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[54] **METHOD AND APPARATUS FOR USE IN OPERATING ON A BONE**

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[52] **U.S. Cl.** **606/87; 606/86; 128/898**

[58] **Field of Search** **606/79, 83, 84, 606/85, 86, 87, 69, 73; 128/898**

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,421,112 12/1983 Mains et al.
4,516,276 5/1985 Mittelmeier et al.
5,015,255 5/1991 Kuslich.
5,026,373 6/1991 Ray et al.
5,053,039 10/1991 Hofmann et al.
5,601,565 2/1997 Huebner.
5,620,448 4/1997 Puddu.
5,669,909 9/1997 Zdeblick et al.
5,722,978 3/1998 Jenkins, Jr.
5,766,251 6/1998 Koshino.

OTHER PUBLICATIONS

Brochure entitled "Arthrex", "Opening Wedge Osteotomy",
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Primary Examiner—Michael Buiz

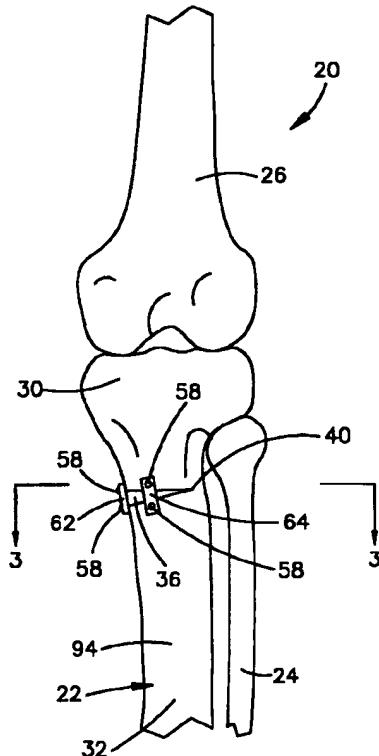
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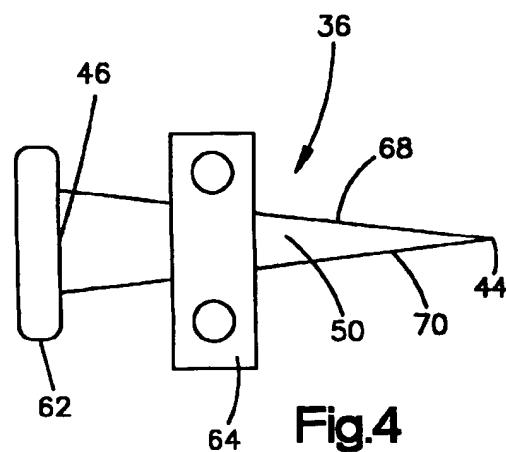
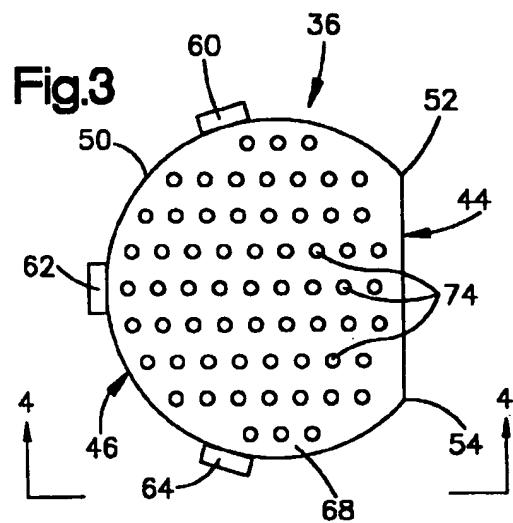
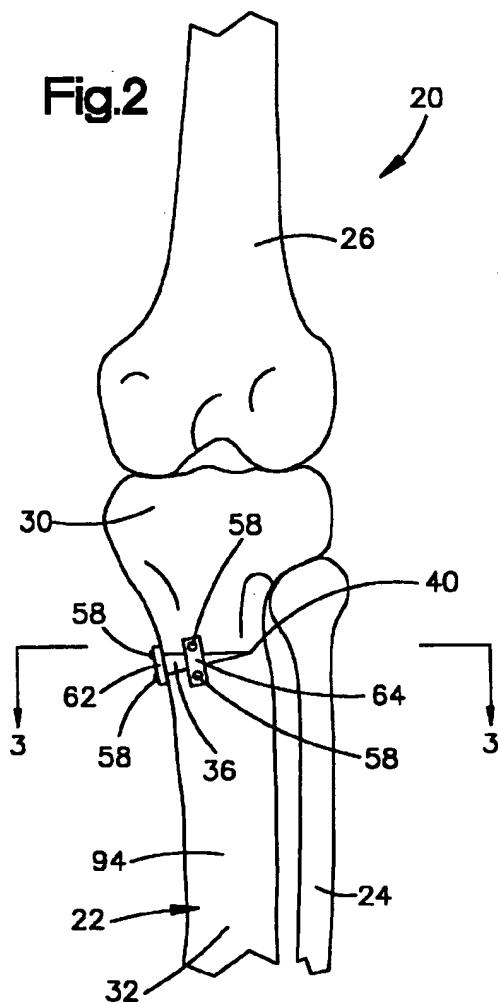
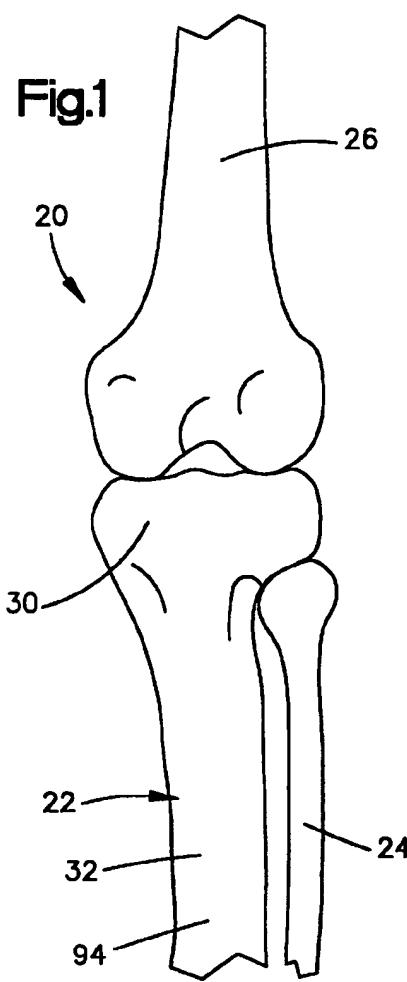
Attorney, Agent, or Firm—Tarolli, Sundheim, Covell, Tummino & Szabo L.L.P.

[57] **ABSTRACT**

The relationship between first and second portions of a bone in a patient's body is changed by moving a wedge member into a slot formed in the bone. Force is applied against hard cortical bone by the wedge member. This force pivots the first portion of the bone relative to the second portion of the bone about an axis extending through bone interconnecting the first and second portions of the bone. As the wedge member moves into the bone, a side surface of the wedge member is moved into alignment with an outer side surface of the bone. The wedge member is fixedly connected with the bone. The wedge member is rigid so that the bone can immediately be load bearing. One or more openings may be provided in the wedge member to enable bone to grow through the wedge member. The wedge member may contain a material which promotes growth of bone through the wedge member.

125 Claims, 5 Drawing Sheets





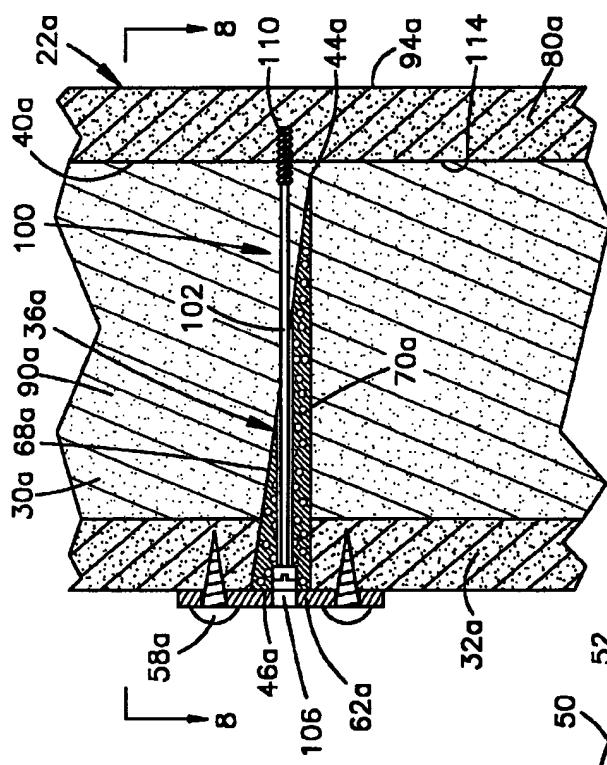


Fig.7

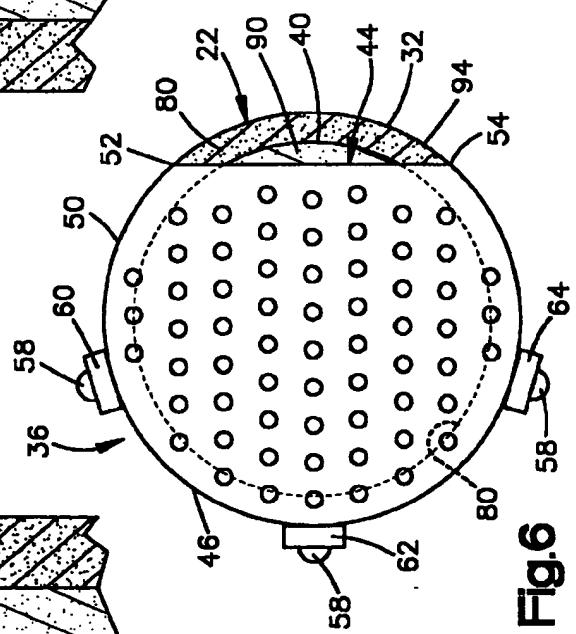


Fig.6

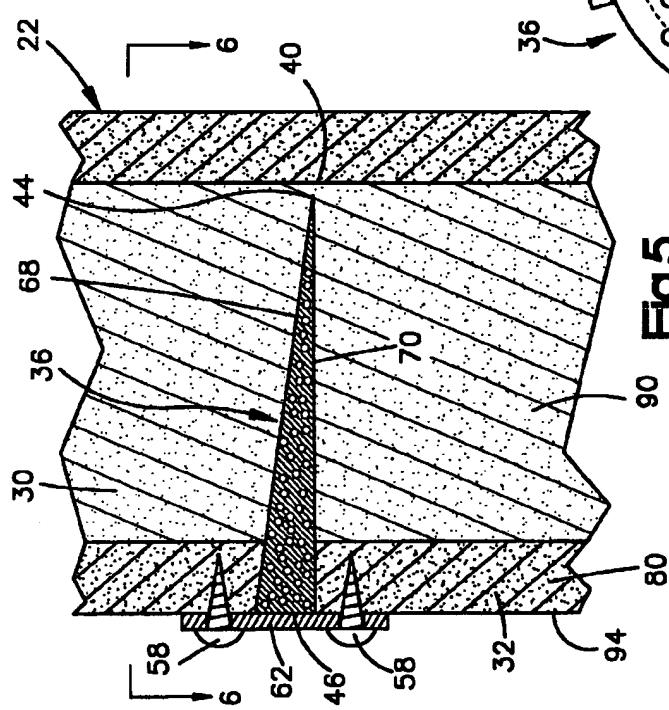
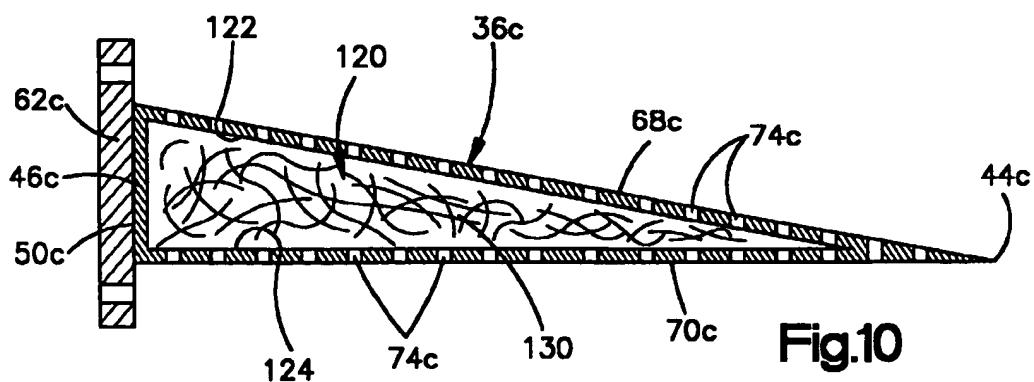
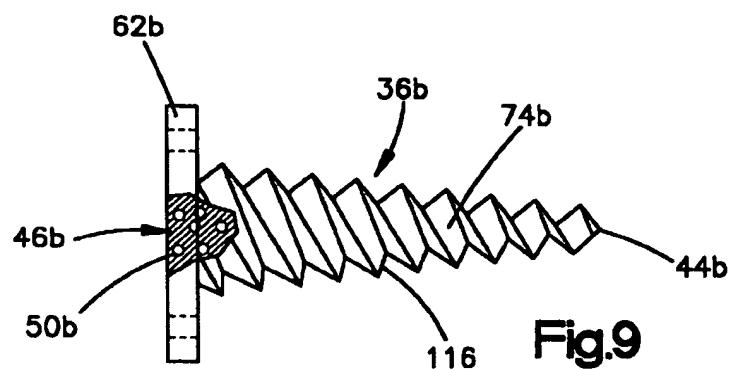
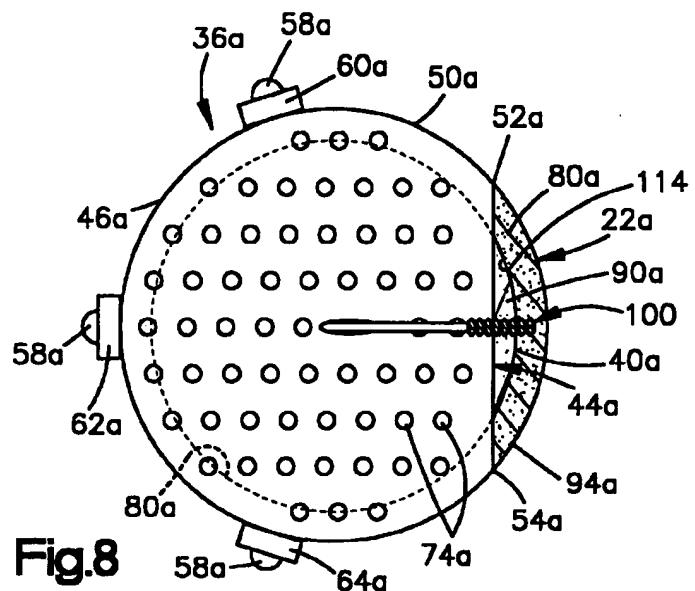


Fig.5



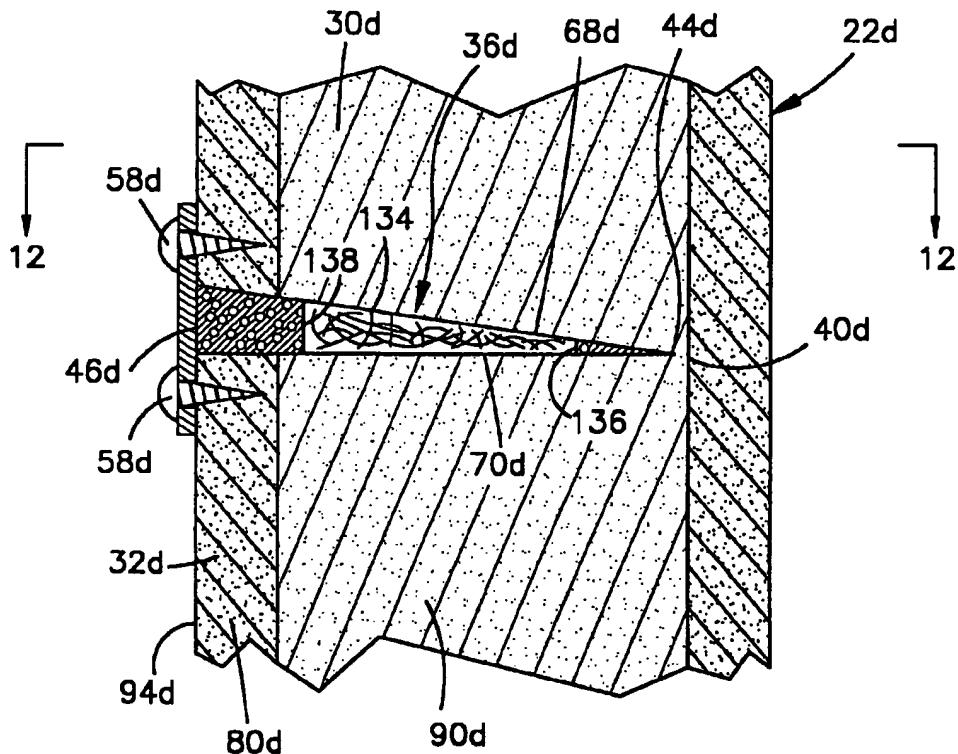


Fig.11

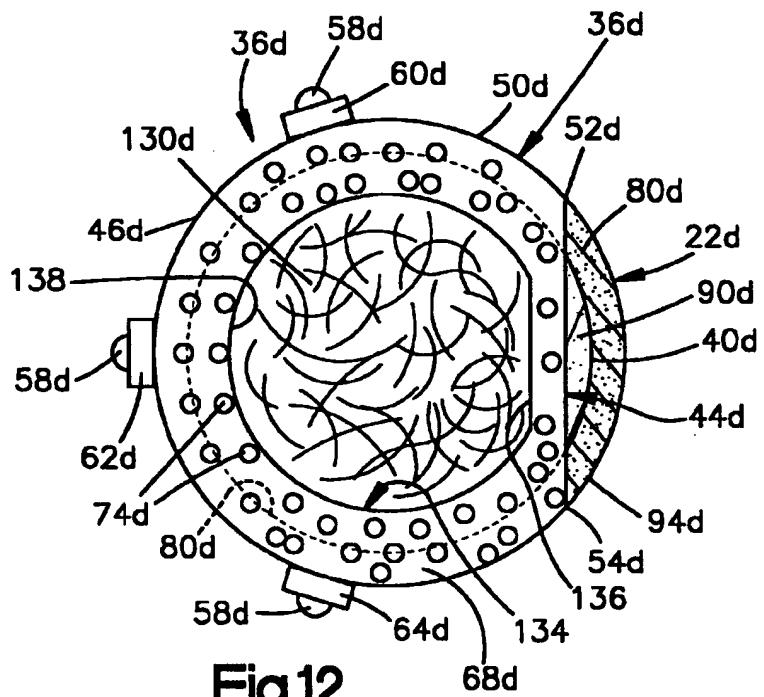


Fig.12

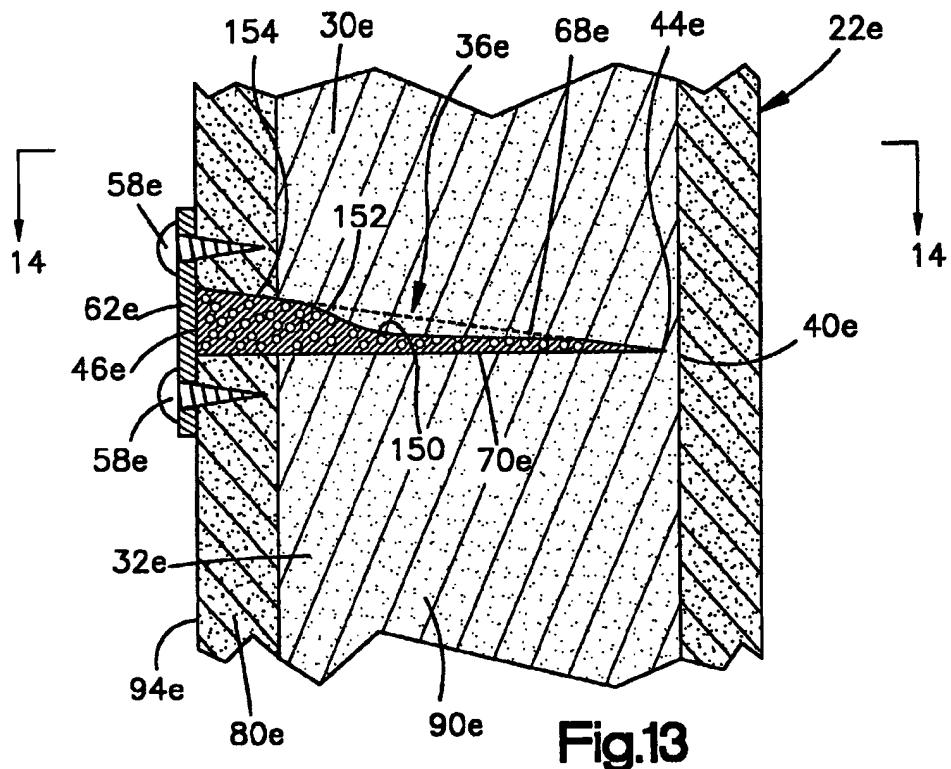


Fig.13

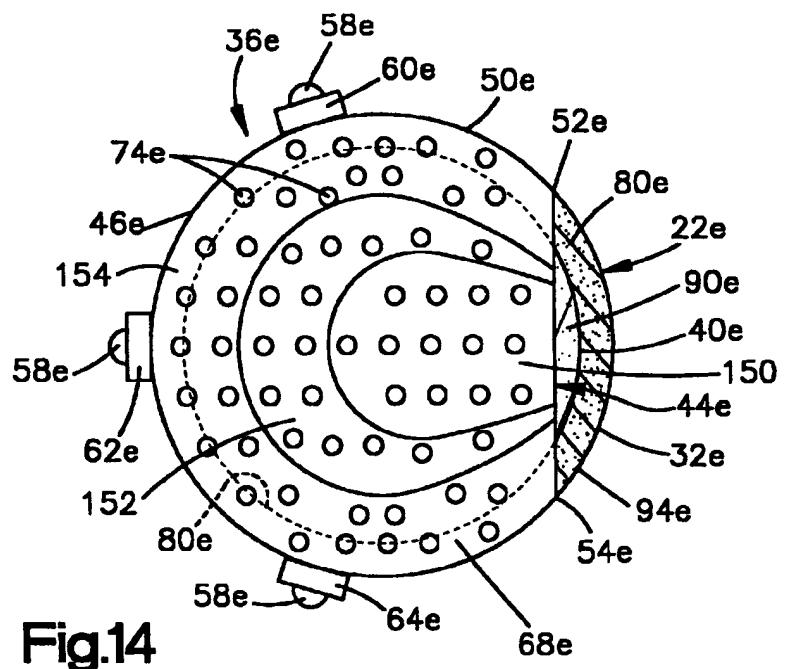


Fig.14

METHOD AND APPARATUS FOR USE IN OPERATING ON A BONE

BACKGROUND OF THE INVENTION

The present invention relates to a new and improved method and apparatus in which a wedge member is used to change a spatial relationship between portions of a bone in a patient's body.

A known method for performing an osteotomy includes forming a slot which extends part way through a bone. A forked wedge tool is inserted into the slot. A plate is then placed in a central opening in the forked wedge tool and positioned against the bone. The plate is secured to the bone. The forked wedge tool is then removed from the opening. This method of performing an osteotomy is disclosed in U.S. Pat. No. 5,620,448.

The foregoing osteotomy changes the spatial relationship between portions of a bone in a patient's body by forming and maintaining a wedge-shaped opening in the bone. In other known methods, the spatial relationship between portions of a bone in a patient's body has been changed by removing a wedged-shaped piece from the bone. The resulting opening is closed to effect the relative movement between portions of the bone. The performance of an osteotomy which includes removing a wedge-shaped piece of bone is disclosed in U.S. Pat. Nos. 5,053,039 and 5,601,565.

SUMMARY OF THE INVENTION

The present invention relates to a new and improved method and apparatus for use in changing a spatial relationship between portions of a bone in a patient's body. When this is to be done, an opening is formed in a portion of the patient's body tissue to at least partially expose the bone. Force is applied to the bone with a wedge member to move one portion of the bone relative to another portion of the bone. The wedge member may be fixedly connected with either or both portions of the bone. The opening in the patient's body is then closed with the wedge member disposed in engagement with the bone. Force can be transmitted between portions of the bone through the wedge member.

The wedge member may taper from a thick edge to a thin edge and have a side surface which extends from one end of the thin edge, along the thick edge, to the opposite end of the thin edge. The side surface of the wedge member may have a cross sectional configuration corresponding to the configuration of a portion of an outer side surface of the bone. This enables the wedge member to be aligned with the outer side surface of the bone.

The wedge member may be positioned relative to the bone at a location where a layer of hard cortical bone encloses soft cancellous bone. Opposite ends of the thin leading edge of the wedge member may be positioned in engagement with the hard cortical bone while a central portion of the thin edge of the wedge member engages the soft cancellous bone. In addition, the layer of hard cortical bone may engage the wedge member adjacent to the side surface of the wedge member.

It is contemplated that the wedge member may have many different constructions. It is believed that it will be advantageous to form the wedge member with one or more openings through which bone can grow. The wedge member may be coated with and/or contain bone growth promoting material. The wedge member may be hollow and contain material which promotes growth of bone through the wedge member.

A screw member may extend ahead of the thin leading edge of the wedge member and engage hard cortical bone. Force may be transmitted from the screw member to the wedge member to move the wedge member relative to the bone. Alternatively, the wedge member may have a circular cross sectional configuration with an external thread convolution to enable the wedge member to be moved into an opening in a bone by rotating the wedge member.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features of the present invention will become more apparent upon a consideration of the following description taken in connection with the accompanying drawings wherein:

10 FIG. 1 is a schematic posterior illustration of the relationship between bones in a patient's body;

15 FIG. 2 is a schematic illustration, generally similar to FIG. 1, illustrating the manner in which a wedge member is utilized to change a spatial relationship between portions of one of the bones of FIG. 1;

20 FIG. 3 is an enlarged plan view, taken generally along the line 3—3 of FIG. 2, illustrating the configuration of the wedge member;

25 FIG. 4 is a side elevational view, taken generally along the line 4—4 of FIG. 3, further illustrating the configuration of the wedge member;

30 FIG. 5 is an enlarged schematic fragmentary sectional view of a portion of one of the bones of FIG. 2 and illustrating the relationship of the wedge member to the bone;

35 FIG. 6 is a plan view, taken generally along the line 6—6 of FIG. 5, further illustrating the relationship of the wedge member to the bone;

40 FIG. 7 is a schematic fragmentary sectional view, generally similar to FIG. 5, illustrating the relationship of a second embodiment of the wedge member to the bone;

45 FIG. 8 is a plan view, taken generally along the line 8—8 of FIG. 7, further illustrating the relationship of the wedge member to the bone;

50 FIG. 9 is a schematic pictorial illustration depicting the construction of a screw which forms another embodiment of the wedge member;

55 FIG. 10 is an enlarged sectional view of an embodiment of the wedge member of FIGS. 3—6 which is hollow and contains material to promote bone growth through the wedge member;

FIG. 11 is a fragmentary schematic sectional view, generally similar to FIG. 5, illustrating the relationship of another embodiment of the wedge member to the bone;

FIG. 12 is a plan view, taken generally along the line 12—12 of FIG. 11 and illustrating the configuration of an opening extending through the wedge member of FIG. 11;

55 FIG. 13 is a schematic fragmentary sectional view, similar to FIGS. 5, 7 and 11, illustrating the relationship of a stepped wedge member to a bone; and

60 FIG. 14 is a plan view, taken generally along the line 14—14 of FIG. 13, further illustrating the configuration of the stepped wedge member.

DESCRIPTION OF SPECIFIC PREFERRED

Embodiments of the Invention

General Description

FIGS. 1 and 2 are schematic posterior illustrations of bones in a leg 20 of a patient. A tibia bone 22 and fibula bone

24 support a femur bone 26. Although bones 22, 24 and 26 in a leg of a patient have been illustrated in FIGS. 1 and 2, it should be understood that the method and apparatus of the present invention may be used in association with bones in many different portions of a patient's body.

In FIG. 1, the upper end portion 30 of the tibia bone 22 is angularly misaligned with the lower portion 32 of the tibia bone. Thus, in FIG. 1, the upper end portion 30 of the tibia bone 22 is offset in a counterclockwise direction by approximately 7 degrees from a desired orientation relative to the lower portion 32 of the tibia bone 22. In accordance with a feature of the present invention, a wedge member 36 (FIGS. 2, 3 and 4) is utilized to change the spatial relationship of the upper end portion 30 of the tibia bone 22 relative to the lower portion 32 of the tibia bone.

The wedge member 36 is formed of a relatively hard rigid material. The wedge member 36 is capable of transmitting force between the upper end portion 30 and the lower portion 32 of the tibia bone 22. This enables the leg 20 of the patient to be weight bearing as soon as the wedge member 36 is positioned in the tibia bone 22. Thereafter, bone may grow through the wedge member 36 between the upper end portion 30 and lower portion 32 of the tibia bone 22.

When the wedge member 36 is to be utilized to change the spatial relationship of the upper end portion 30 (FIG. 2) of the tibia bone 22 relative to the lower portion 32 of the tibia bone, an opening is formed in the fleshy part of the body tissue in the leg of the patient to expose the portion of the tibia bone where the wedge member is to be installed. It is contemplated that it may be preferred to install the wedge member 36 approximately two to three millimeters below the upper end of the tibia bone. The specific location where the wedge member 36 is installed will depend upon the surgeon's judgment. It is contemplated that the wedge member 36 may be installed at any one of many locations relative to a particular bone.

A saw cut is made to form a slot at the location where the wedge member 36 is to be installed. The saw cut and resulting slot extend only part way through the tibia bone 22. This results in the upper end portion 30 of the tibia bone 22 being connected with the lower portion 32 of the tibia bone by a connector or hinge portion 40 (FIG. 2) of the tibia bone.

Once a slot has been formed between the upper end portion 30 and lower portion 32 of the tibia bone, the wedge member 36 is moved into the slot. A thin edge 44 (Figs. 3 and 4) of the wedge member 36 is leading and a thick edge 46 of the wedge member trailing as the wedge member moves into the slot. As the wedge member 36 is forced into the slot between the upper end portion 30 and lower portion 32 of the tibia bone 22 (FIG. 2), the wedge member pivots the upper end portion of the tibia bone in a clockwise direction (as viewed in FIG. 2) relative to the lower portion of the tibia bone about an axis extending through the connector or hinge portion 40.

The wedge member 36 has an outer side surface 50 (FIGS. 3 and 4) which extends from one end 52 (FIG. 3) of the thin edge 44 of the wedge member 36 along the thick edge 46 of the wedge member to the opposite end 54 of the thin edge 44. The outer side surface 50 of the wedge member 36 has the same configuration as the outer side surface of the tibia bone 22 at the location where the saw cut formed the slot between the upper end portion 30 and lower portion 32 of the tibia bone. The outer side surface 50 of the wedge member may be formed in a plurality of sections.

Although the outer side surface 50 of the wedge member 36 has been illustrated schematically in FIG. 3 as forming a portion of a circle, it should be understood that the outer side

surface 50 of the wedge member 36 will probably not have a configuration which corresponds to the configuration of a portion of a circle. The configuration of the outer side surface 50 of the wedge member 36 conforms to the cross sectional configuration of the outside surface of the bone 22 at the location where the wedge member is to be installed in the bone.

Since the outer side surface 50 of the wedge member 36 has a configuration corresponding to the configuration of the outer side surface of the bone 22 at the location where the wedge member is to be installed in the tibia bone (FIG. 2), the outer side surface 50 (FIG. 3) of the wedge member can be moved into alignment with the outer side surface of the bone 22. This enables a hard cortical outer layer of the bone 22 to engage opposite major sides of the wedge member 36 adjacent to the outer side surface 50 of the wedge member. The outer layer of hard cortical bone has continuous engagement with the wedge member 36 from the thin edge 44 to the thick edge 46 of the wedge member. This maximizes the extent of engagement of the hard outer layer of cortical bone with the wedge member 36 to avoid stress concentrations in the hard cortical outer layer.

If the wedge member 36 did not have an outer side surface 50 which extended along the outer side surface of the bone 22 from opposite sides of the hinge portion 40 of the bone, the hard cortical outer layer of bone would only be partially supported by the wedge member 36 at the slot in the bone. This would result in the load which is transmitted between the upper end portion 30 of the bone 22 and the lower portion 32 of the bone being concentrated at a relatively small area on the hard cortical outer layer of bone at the opening to the slot.

Once the wedge member 36 has been positioned relative to the bone 22, in the manner illustrated in FIG. 2, the wedge member is fixedly connected with the bone. In the illustrated embodiment of the invention, suitable screws 58 (FIG. 2) are used to fixedly connect mounting strips 60, 62 and 64 (FIG. 3) with the upper end portion 30 and lower portion 32 of the tibia bone 22. The mounting strips 60, 62 and 64 and screws 58 hold the wedge member 36 against movement relative to the bone 22 during subsequent loading of the bone by the patient.

The opening in the fleshy portion of the leg of the patient is then closed. Since the wedge member 36 has a rigid structure, the leg 20 of the patient can be load bearing immediately after closing of the opening which exposed the bone 22. With the passage of time, bone grows through the wedge member 36 between the upper end portion 30 and lower portion 32 of the bone 22.

Wedge Member

The wedge member 36 (FIGS. 3 and 4) has upper and lower major side surfaces 68 and 70 (FIG. 4). The upper and lower major side surfaces 68 and 70 slope toward each other from the thick edge 46 to the thin edge 44 of the wedge member 36. It is contemplated that a plurality of wedge members 36 having different acute angles between upper and lower major side surfaces 68 and 70 may be provided. This enables a surgeon to select a wedge member 36 having a desired thickness at the thick edge 46.

The acute angle between the flat upper and lower major side surfaces 68 and 70 is determined by the extent to which the spatial relationship between the upper end portion 30 and the lower portion 32 (FIGS. 1 and 2) of the bone 22 is to be changed by insertion of the wedge member 36. Of course, the larger the bone with which the wedge member 36 is used, the smaller is the angle between the upper and lower major side surfaces 68 and 66 to obtain a desired thickness of the wedge member at the thick edge 46 of the wedge member.

It is believed that it may be desired to have the angle between the upper and lower major side surfaces 68 and 70 be within a range between one degree and twenty degrees. Although the specific angle provided between the upper and lower major side surfaces 68 and 70 will depend upon the environment in which the wedge member is to be utilized, it is believed that the angle between the upper and lower major side surfaces 68 and 70 may frequently be between two degrees and ten degrees. It should be understood that the foregoing specific ranges of sizes for the angle between the upper and lower major side surfaces 68 and 70 have been set forth herein for purposes of clarity of description and it is contemplated that the angle between the upper and lower major side surfaces may be any one of many angles other than these specific angles.

The wedge member 36 may be formed of any one of many different known materials which are compatible with a patient's body. For example, the wedge member may be formed of human or animal bone, stainless steel, tantalum, a porous ceramic, or a polymeric material. If desired, the wedge member 36 may be formed of a biodegradable material. However, it is preferred to have the wedge member 36 formed of a rigid material which is capable of enabling the leg 20 to be weight bearing immediately after the wedge member 36 has been installed in the bone 22.

The wedge member 36 is porous so that bone can grow through the wedge member. In the illustrated embodiment of the invention, the wedge member 36 has a plurality of openings or passages 74 which extend through the wedge member between the upper and lower major side surfaces 68 and 70. The openings 74 enable bone to grow through the wedge member 36.

It is believed that it may be preferred to form the wedge member of an open cell material to provide cavities in which bone can grow through the wedge member. The wedge member 36 may have a cellular construction similar to coral. Alternatively, straight passages may be drilled or cast in the wedge member 36. It is contemplated that the wedge member 36 may be coated with a material which promotes the growth of bone. If the wedge member 36 has a cellular construction, the cells may be at least partially filled with bone growth promoting material.

When the wedge member 36 is to be inserted into the bone 22 to change the spatial relationship between the upper end portion 30 of the bone and the lower portion 32 of the bone, a location for insertion of the wedge member is selected by a surgeon. It is contemplated that it may be desired to locate the wedge member 36 approximately two to five millimeters below the upper end of the tibia bone. However, the specific location at which the wedge member is inserted into the bone 22 will be selected by the surgeon as a function of the result desired from a particular operation.

A saw slot is formed at the location where the wedge member is to be inserted into the bone. The slot extends only part way through the bone. Thus, in FIG. 2, the slot extended from the left side of the tibia bone 22 toward the right side to a location which was spaced from the right side of the tibia bone. This results in the upper end portion 30 and lower portion 32 of the bone 22 being interconnected by a connector or hinge portion 40 after the slot is formed. The thickness of the hinge portion 40 will depend upon the location where the wedge member is being installed, the extent to which the spatial relationship between portions of the bone are to be changed by insertion of the wedge member, and the physical characteristics of the bone itself.

Once the slot has been formed, with a saw or other device at a desired location in the bone, the wedge member 36 is

moved into the slot. The thin edge 44 of the wedge member is easily inserted into an entry opening to the slot. Force is then applied against the thick edge 46 of the wedge member to move the wedge member further into the slot.

When the thin edge 44 of the wedge member 36 is initially positioned in the slot, the thin edge of the wedge member is diametrically opposite from the hinge portion 40 of the bone 22. A longitudinal axis of the thin edge 44, that is an axis extending between the opposite ends 52 and 54 (FIG. 3) of the thin edge, is parallel to the bottom of the slot when the thin edge is initially positioned in the slot. At this time, an axis perpendicular to the thin edge 44 and extending through the center of the wedge member 36 is aligned with an axis extending perpendicular to the bottom of inner edge of the slot and extending through the center of the bone 22.

The wedge member 36 is then moved into the slot along a linear path which extends perpendicular to the bottom or inner end of the slot and to the thin edge 44 of the wedge member. As the wedge member 36 moves into the slot along the linear path, the upper major side surface 68 (FIGS. 4 and 5) of the wedge member slides along and applies force against the upper end portion 30 of the tibia bone 22. As the wedge member 36 moves into the slot along the linear path, the lower major side surface 70 of the wedge member slides along and applies force against the lower portion 32 of the tibia bone 22. The wedge member 36 is moved into the slot under the influence of force applied against the trailing thick edge portion 46.

Although it is contemplated that the wedge member 36 could be mounted at many different locations in many different types of bone, the wedge member 36 is illustrated in FIGS. 5 and 6 as being positioned in the tibia bone 22 at a location in which an outer layer 80 of hard cortical bone extends around a core 90 of soft cancellous bone.

As the thin leading edge 44 of the wedge member 36 moves into the slot, the central portion of the thin leading edge 44 engages the outer layer 80 of hard cortical bone at the entry to the slot on a side of the bone 22 opposite from the hinge or connector portion 40. Force is applied against the outer layer 80 of hard cortical bone by the upper and lower major side surfaces 68 and 70 of the wedge member 36 at a location adjacent to the center of the opening to the slot. The force applied against the outer layer 80 of hard cortical bone by the thin leading end portion of the wedge member 36 initiates pivotal movement of the upper end portion 30 of the bone 22 about an axis extend through the hinge portion 40.

As the thin edge 44 of the wedge member moves further into the slot, the area of engagement of the thin leading edge 44 of the wedge member with the outer layer 80 of hard cortical bone moves outward from a central portion of the thin leading edge 44 toward the opposite ends 52 and 54 of the thin leading edge 44 (FIGS. 3 and 6). The upper and lower major sides 68 and 70 of the wedge member move into engagement with the layer 80 of hard cortical bone along opposite sides of the bone 22.

As the area of engagement of the thin leading edge 44 of the wedge member 36 with the outer layer 80 of hard cortical bone moves toward the opposite ends of the thin edge 44, the central portion of the thin edge 44 engages the core 90 of soft cancellous bone. When the central portion of the thin edge 44 of the wedge member 36 engages the core 90 of soft cancellous bone, portions of the thin edge 44 on opposite sides of the central portion of the thin edge are in engagement with the outer layer 80 of hard cortical bone. However, depending upon the thickness and/or configuration of the outer layer 80 of hard cortical bone, the central portion of the

thin edge 44 may or may not engage the core 90 of soft cancellous bone before the opposite ends 52 and 54 of the thin edge 44 of the wedge member 36 move into initial engagement with the outer layer 80 of hard cortical bone.

Continued movement of the wedge member 36 toward the bottom of the slot in the bone 22, that is, toward the right as viewed in FIGS. 5 and 6, moves the entire thin leading edge 44 of the wedge member into engagement with the core 90 of soft cancellous bone. As this occurs, the wedge member 36 moves into engagement with the outer layer 80 of hard cortical bone along opposite sides of the wedge member adjacent to the outer side surface 50 of the wedge member and adjacent to opposite sides of the bone 22. Although the thin leading edge 44 of the wedge member is in engagement with the core 90 of soft cancellous bone, the upper and lower major side surfaces 68 and 70 of the wedge member 36 are sliding along the portion of the outer layer 80 of hard cortical bone disposed behind the thin leading edge 44 of the wedge member 36, that is, to the left as viewed in FIGS. 5 and 6.

When the thin leading edge 44 of the wedge member 36 has moved rightward (as viewed in FIGS. 5 and 6) past the center of the bone 22, the opposite ends 52 and 54 of the thin leading edge again move into engagement with the outer layer 80 of hard cortical bone. Continued movement of the wedge member 36 into the slot increases the extent of engagement of the thin leading edge 44 of the wedge member with the outer layer 80 of hard cortical bone.

When the outer side surface 50 of the wedge member 36 has moved into alignment with an outer side surface 94 (FIG. 6) on the lower portion 32 of the bone 22, rightward (as viewed in FIG. 6) movement of the wedge member is interrupted. At this time, the thin leading edge 44 of the wedge member is at the bottom of the saw slot formed in the bone 22. Opposite ends 52 and 54 of the thin leading edge 44 are disposed in engagement with the outer layer 80 of hard cortical bone. The mounting strips 60, 62 and 64 are disposed in abutting engagement with the outer side surface 94 of the bone 22. Therefore, further rightward movement of the wedge member 36 into the slot is blocked and the wedge member is in the position illustrated in FIGS. 5 and 6 relative to the bone 22.

During movement of the wedge member 36 into the slot in the bone 22, in the manner previously described, the upper portion 30 of the bone pivoted relative to the lower portion 32 by force applied against the upper and lower portions of the bone by the wedge member 36. The upper end portion 30 of the bone 22 is pivoted relative to the lower portion 32 of the bone about an axis extending parallel to the thin leading edge 44 of the wedge member 36 and extending through the connector or hinge portion 40 of the bone 22.

When the outer side surface 50 on the wedge member 36 is moved into alignment with the outer side surface 94 on the bone 22, the outer side surface 50 on the wedge member 36 will form a continuation of the outer side surface 94 of the bone 22. Although perfect alignment of the outer side surface 50 of the wedge member 36 with the outer side surface 94 of the bone is desired, there may be a slight misalignment or discontinuity where the outer side surface 50 of the wedge member 36 is aligned with the outer side surface 94 of the bone 22.

In the embodiment of the wedge member 36 illustrated in FIGS. 3-6, the wedge member has been shown as being formed as a portion of a circle with the thin edge 44 being a chord of the circle. However, it is believed that it will be preferred to form the wedge member 36 with a configuration which matches the configuration of the bone 22 in which the wedge member is to be inserted. Thus, it is contemplated

that the bone 22 may have an irregular outer side surface 94 which is not formed as a portion of a circle. In such a situation, the outer side surface 50 of the wedge member 36 would have a matching irregular configuration and would not be formed as a portion of a cylinder.

By having the outer side surface 50 of the wedge member 36 have a configuration which is the same as the configuration as the outer surface 94 of the bone 22, almost perfect alignment can be obtained between the wedge member 36 and the bone 22. Although there may be some misalignment of the wedge member 36 and outer side surface 94 of the bone 22, the outer layer 80 of hard cortical bone is disposed in engagement with the upper and lower major side surfaces 68 and 70 of the wedge member 36 adjacent to the outer side surface 50 of the wedge member throughout the extent of the outer side surface of the wedge member.

By providing for engagement of the outer layer 80 of hard cortical bone with the wedge member 36 throughout the extent of the opening to the slot which was formed in the bone 22, the area for transmittal of force between the upper and lower major side surfaces 68 and 70 (FIG. 5) of the wedge member and the outer layer 80 of hard cortical bone is maximized. This is because the entire extent of the outer layer 80 of cortical bone which has been cut to form the slot is disposed in engagement with the wedge member 36. The only portion of the outer layer 80 of hard cortical bone which does not engage the wedge member 36 is the portion of the outer layer of hard cortical bone which is disposed in the connector or hinge portion 40 of the tibia bone 22 (FIGS. 5 and 6). Therefore, there is no open space between surfaces on the outer layer 80 of hard cortical bone where the slot was formed. This minimizes any tendency for stress concentrations to occur due to insertion of the wedge member 36 into the bone 22.

As was previously indicated, it is desired to have almost perfect alignment of the outer side surface 50 of the wedge member 36 with the outer side 94 of the bone 22. However, the obtaining of perfect alignment of the outer side surface 50 and the wedge member 36 with the outer side surface 94 on the bone 22 will be difficult due to the fact that bones on different patients do not have exactly the same configuration. In addition, the obtaining of perfect alignment between the outer side surface 50 of the wedge member 36 and the outer side surface 94 of the bone 22 is made difficult due to the fact that the configuration of the outer side surface 94 of the bone 22 varies along the extent of the bone.

The outer side surface 50 of the wedge member 36 is considered as being aligned with the outer side surface 94 of the bone 22 when there is a slight discontinuity between the outer side surface 94 of the bone and the outer side surface 50 of the wedge member 36. However, the extent of this discontinuity should be minimized. Close alignment of the outer side surface 50 of the wedge member 36 with the surface 94 on the bone 22 maximizes the extent of engagement of the outer layer 80 of hard cortical bone with the wedge member. In addition, close alignment of the outer side surface 50 of the wedge member 36 with the surface 94 on the bone 22 minimizes the extent to which the wedge member projects outward from the outer side surface of the bone.

Once the wedge member 36 has been positioned relative to the bone 22, in the manner previously explained, the screws 58 are used to fixedly connect the wedge member 36 with the upper end portion 30 and lower portion 32 of the bone 22. The screws 58 engage the outer layer of hard cortical bone (FIG. 5) to hold the wedge member 36 against movement relative to the bone 22. It is contemplated that the

wedge member 36 could be connected with the bone 22 in a manner other than by using screws 58.

Since the wedge member 36 is rigid, it can immediately transmit loads between the upper end portion 30 and lower portion 32 of the tibia bone 22. Therefore, after the incision which exposed the site at which the wedge member 36 is inserted into the bone 22 has been closed, the patient can begin to apply weight to the leg 20. This weight will be transmitted through the entire extent of the outer layer 80 of hard cortical bone. Thus, the portion of the outer layer 80 of hard cortical bone in the connector or hinge portion 40 of the tibia bone 22 is not severed and can transmit force in the usual manner. The portion of the outer layer 80 of hard cortical bone which was cut to form the slot into which the wedge 36 was inserted, engages the upper and lower major side surfaces 68 and 70 of the wedge member 36. Since the wedge member 36 is rigid, force can be transmitted between the portions of the outer layer 80 of hard cortical bone which engage the wedge member.

The central portion of the wedge member 36 engages the core 90 of soft cancellous bone. Since the wedge member 36 is porous, the soft cancellous bone can grow through openings formed in the wedge member 36 to fuse the upper end portion 30 and lower portion 32 of the bone 22. The growth of the soft cancellous bone through the wedge member 36 may be promoted by coating the wedge member with known bone growth inducing substances. In addition, it is believed that the hard cortical bone of the outer layer 80 will eventually grow through openings 74 in the wedge member 36. The openings 74, which extend through the wedge member 36, may have a straight cylindrical configuration or may have an irregular configuration, similar to the configuration of openings or cavities formed in natural coral.

In the illustrations of FIGS. 5 and 6, the wedge member 36 is positioned in bone 22 at a location where an outer layer 80 of hard cortical bone extends around a core 90 of soft cancellous bone. However, the wedge member 36 could be used at locations where one or both major side surfaces 68 and 70 are engaged by only hard cortical bone. Although the wedge member 36 has been illustrated in FIG. 2 being used in a bone 22 in a patient's leg 20, the wedge member could be used with other bones. For example, the wedge member 36 could be used in association with bones in a patient's arm, wrist, hand, ankle or foot.

In the embodiment of the invention illustrated in FIGS. 2-6, the openings 74a are provided in the wedge member 36a to enable bone to grow through the wedge member. If desired, the openings 74a could be omitted.

Wedge Member—Second Embodiment

In the embodiment of the wedge member 36 illustrated in FIGS. 2-6, the wedge member is pushed into a slot formed in the bone 22 by the application of force against the thick edge 46 of the wedge member. In the embodiment of the invention illustrated in FIGS. 7 and 8, a long thin screw member is utilized to guide at least a portion of the movement of the wedge member into the bone and to apply force to the wedge member to pull the wedge member into the slot formed in the bone. Since the embodiment of the invention illustrated in FIGS. 7 and 8 is generally similar to the embodiment of the invention illustrated in FIGS. 2-6, similar numerals will be utilized to designate similar components, the suffix letter "a" being associated with the numerals of FIGS. 7 and 8 to avoid confusion.

A wedge member 36a is inserted into a bone 22a to change the spatial relationship of an upper portion 30a (FIG. 7) of the bone relative to a lower portion 32a of the bone. The wedge member 36a has a thin edge 44a and a thick edge

46a. An outer side surface 50a (FIG. 8) extends between opposite ends 52a and 54a of the thin edge 44a (FIG. 8). Upper and lower major side surfaces 68a and 70a (FIG. 7) extend between the thin edge 44a and the thick edge 46a. The flat upper and lower major side surfaces 68a and 70a are skewed at an acute angle relative to each other.

Openings 74a (FIG. 8) extend through the wedge member 36a to enable bone to grow through the wedge member. The opening 74a may have a straight cylindrical configuration or may have an irregular configuration, similar to openings formed in natural coral. The wedge member 36a may be coated with bone growth promoting material and/or the openings 74a filled with bone growth promoting material. If desired, the openings 74a may be omitted.

A plurality of mounting strips 60a, 62a and 64a (FIG. 8) engage an outer side surface 94a of the bone 22a. Suitable fasteners 58a connect the wedge member 36a with the bone 22a. The outer side surface 50a on the wedge member 36a is aligned with the outer side surface 94a of the bone 22a.

The wedge member 36a has the same general construction as the wedge member 36 of FIGS. 1-6. The wedge member 36a is inserted into a slot formed in the bone 22a in much the same manner as previously described in connection with the embodiment of the invention illustrated in FIGS. 1-6. However, in accordance with a feature of the embodiment of the invention illustrated in FIGS. 7 and 8, a screw member 100 is utilized to guide movement of the wedge member 36a relative to the bone 22a and to apply force to the wedge member 36a to pull the wedge member into a slot formed in the bone 22a.

The screw member 100 has a straight elongated shank 102 (FIG. 7) which extends through the wedge member 36a. A head end portion 104 of the screw member 100 is fixedly connected with the shank 102 and disposed in a suitable recess formed in the wedge member 36a. An opening 106 is formed in the mounting strip 62a to provide access to the head end portion 104 of the screw member 100.

The screw member 100 has an externally threaded end portion 110 disposed on the end of the shank 102 opposite from the head end portion 104. The externally threaded end 110 of the screw member 100 is engageable with the outer layer 80a of hard cortical bone at the hinge or connector section 40a of the bone 22a.

When the wedge member 36a is to be inserted into a slot in the bone 22a, the wedge member 36a is moved into the slot in the manner previously explained in conjunction with the embodiment of the invention illustrated in FIGS. 2-6. As the wedge member 36a approaches the position shown in FIG. 7, the externally threaded end 110 of the screw member 100 engages an inner side surface 114 of the outer layer 80a of hard cortical bone. The head end portion 104 of the screw member 100 is then rotated. This causes the externally threaded end portion 110 of the screw member to move into threaded engagement with the outer layer 80a of hard cortical bone.

Continued rotation of the screw member 100 results in the head end portion 104 applying force against the wedge member 36a to pull the wedge member toward the right (as viewed in FIG. 7). As the wedge member 36a is pulled toward the right by force transmitted from the screw member 100 to the wedge member, the mounting strips 60a, 62a and 64a (FIG. 8) move into abutting engagement with the outer side surface 94a on the bone 22a. The shank 102 of the screw member 100 guides movement of the wedge member 36a relative to the bone 22a. Rotation of the screw member 100 and movement of the wedge member 36a toward the right (as viewed in FIG. 7) is then interrupted. The mounting

strips 60a, 62a, and 64a are fixedly connected with the upper end portion 30a and lower portion 32a of the bone 22a by fasteners (screws) 58a.

Although the wedge member 36a has been illustrated in FIGS. 7 and 8 at a location where a layer 80a of hard cortical bone encloses a core 90a of soft cancellous bone, the wedge member 36a could be used at a location where the wedge member engages only hard cortical bone. Although it is preferred to provide the openings 74a to enable bone to grow through the wedge member 36a, the openings may be omitted if desired.

Wedge Member—Third Embodiment

In the embodiment of the wedge member illustrated in FIGS. 2-8, the wedge member has flat major side surfaces which extend from a relatively thick edge 46 of the wedge member to a relatively thin edge 44 of the wedge member. In the embodiment of the invention illustrated in FIG. 9, the wedge member is formed as an axially tapered screw. Since the wedge member of the embodiment of the invention illustrated in FIG. 9 changes the spatial relationship between end portions of a bone in a patient's body in a manner similar to that explained in conjunction with the embodiments of the invention illustrated in FIGS. 2-7, similar numerals will be utilized to identify components of the embodiment of the invention illustrated in FIG. 9, the suffix letter "b" being associated with the numerals of FIG. 9 to avoid confusion.

A wedge member 36b has a thin edge or point 44b and a thick edge or head 46b (FIG. 9). A mounting strip 62b is connected with the thick edge 46b and engages an outer side surface of a bone to limit movement of the wedge member 36b relative to the bone. A side surface 50b on the thick edge 46b of the wedge member 36b is aligned with an outer side surface of the bone when the mounting strip 62b engages the outer side surface of the bone.

In accordance with a feature of this embodiment of the invention, the wedge member 36b has a spiral external thread convolution 116. The thread convolution 116 has a generally conical configuration and tapers from the thick edge 50b of the wedge member 36b to the thin edge or point 44b of the wedge member 36b.

When the wedge member 36b is to be inserted into a bone, a slot is formed in the bone in the same manner as previously explained in conjunction with the embodiment of the invention illustrated in FIGS. 2-8. The wedge member 36b is then screwed into the slot. In order to screw the wedge member 36b into the slot, force may be applied to the mounting strip 62b to rotate the wedge member 36b about its longitudinal central axis. Alternatively, a socket may be provided in the thick edge 46b to receive a suitable tool which transmits torque to the wedge member 36b.

As this occurs, the external thread convolution 116 on the wedge member 36b cooperates with the hard cancellous outer layer of the bone to effect axial movement of the wedge member into the slot in the bone. As the wedge member 36b enters the slot in the bone, the portion of the bone, corresponding to the upper end portion 30 of FIG. 2, pivots relative to a lower portion 32. This results in a change in the spatial relationship between the upper portion and lower portion of the bone.

Prior to moving the wedge member 36b into the slot in the bone, a longitudinal central axis of the wedge member is aligned with an axis which is perpendicular to a bottom of the slot and extends through the center of the bone. The wedge member 36b is then rotated about its longitudinal central axis. As the wedge member 36b rotates and moves into the slot, the wedge member moves along a straight path which extends perpendicular to an axis about which the

upper end portion of the bone is pivoted relative to the lower portion of the bone. Movement of the wedge member 36b into the slot is interrupted with the thin edge or point 44b spaced from a connector or hinge portion of the bone which interconnects the upper end portion and lower portion of the bone.

A plurality of openings 74b are formed in the wedge member 36b to enable bone to grow through the wedge member in the manner previously explained in conjunction with the embodiment of FIGS. 1-8. The wedge member 36b is coated with a bone growth promoting material. The wedge member 36b may be hollow to provide a cavity to hold bone growth promoting material.

Wedge Member—Fourth Embodiment

In the embodiment of the invention illustrated in FIGS. 2-9, the wedge member has openings to enable bone to grow through the wedge member. In the embodiment of the invention illustrated in FIG. 10, the wedge member is hollow to provide a cavity which holds bone growth promoting material. Since the embodiment of the invention illustrated in FIG. 10 is generally similar to the embodiment of the invention illustrated in FIGS. 2-9, similar numerals will be utilized to designate similar components, the suffix letter "c" being associated with the embodiment of FIG. 10 to avoid confusion.

A wedge member 36c (FIG. 10) has a thin edge 44c and a thick edge 46c. An outer side surface 50c extends between opposite ends of the thin edge 44c in the same manner as is illustrated in FIGS. 3 and 6 for the embodiment of the invention of FIGS. 2-6. The wedge member 36c has the same overall configuration as the wedge member 36 of FIGS. 2-6.

A mounting strip 62c is connected with the thick edge 46c of the wedge member 36c. Additional mounting strips, corresponding to the mounting strips 60 and 64 of the embodiment of the invention illustrated in FIGS. 3 and 6, are provided on the wedge member 36c. When the outer side surface 50c on the wedge member 36c has moved into alignment with the outer side surface of the bone, the mounting strip 62c engages the outer side surface of the bone. Suitable fasteners may be used to interconnect the bone and the mounting strip 62c. Although only a single mounting strip 62c has been illustrated in FIG. 10, it should be understood that additional mounting strips, corresponding to the mounting strips 62 and 64 of FIG. 3, are associated with the wedge member 36c.

The wedge member 36c has a flat upper major side surface 68c and a flat lower major side surface 70c. The upper and lower major side surfaces 68c and 70c have the same configuration as the upper and lower major side surfaces 68 and 70 of the embodiment of the invention illustrated in FIGS. 2-6. The outer side surface 50c has the same configuration as the outer side surface 50 of the embodiment of the invention illustrated in FIGS. 2-6. The upper and lower major side surfaces 68c and 70c (FIG. 10) are disposed at an acute angle and taper from the thick edge 46c to the thin edge 44c of the wedge member 36c.

The wedge member 36c is rigid to enable it to be weight bearing as soon as it is positioned in a bone. Although the wedge member 36c could be formed of many different materials, it is formed of stainless steel.

In accordance with a feature of this embodiment of the invention, the wedge member 36c (FIG. 10) is hollow. Therefore, a compartment or cavity 120 is formed in the wedge member 36c. The compartment 120 has upper and lower inner side surfaces 122 and 124 which are smaller than the upper and lower major side surfaces 68c and 70c of the

wedge member 36c. However, the inner side surfaces 122 and 124 of the compartment 120 have the same general configuration as the upper and lower major side surfaces 68c and 70c of the wedge member 36c.

The compartment 120 is filled with a bone growth inducing material 130. The bone growth inducing material 130 is positioned in the compartment 120 through a suitable opening (not shown) formed in either the upper major side surface 68c or the lower major side surface 70c of the wedge member 36c. Once the compartment 120 has been filled with the bone growth inducing material 130, the opening to the compartment is closed. However, openings 74c in the wedge member 36c enable bone to grow through the wedge member.

The growth of bone through the wedge member 36c is promoted by the bone growth inducing material 130 in the compartment 120. The bone growth inducing material 130 in the compartment 120 may be any one of many known compositions. For example, apatite compositions with collagen may be utilized. Demineralized bone powder may also be utilized. Regardless of which of the known bone growth inducing materials are selected, the presence of the bone growth inducing material in the compartment 120 will promote a growth of bone through the openings 74c in the wedge member 36c.

The wedge member 36c may, itself, be formed of a suitable rigid material, such as tantalum or stainless steel. In addition to the bone growth inducing material 130 in the compartment 120, the surfaces of the wedge member 36c and the openings 74c may be coated with suitable bone growth inducing materials. Although the wedge member 36c has been shown as having straight cylindrical openings 74c through which bone grows, the wedge member 36c could have an open celled construction if desired.

Wedge Member—Fifth Embodiment

In the embodiment of the invention illustrated in FIGS. 2-10, a plurality of relatively small openings 74 extend through the various wedge members to enable bone to grow through the wedge members. In the embodiment of the invention illustrated in FIGS. 11 and 12, a relatively large central opening is provided in the wedge member to enable bone to grow through the wedge member. Since the embodiment of the invention illustrated in FIGS. 11 and 12 is generally similar to the embodiment of the invention illustrated in FIGS. 2-10, similar numerals will be utilized to designate similar components, the suffix letter "d" being associated with the numerals of FIGS. 11 and 12 to avoid confusion.

A wedge member 36d (FIGS. 11 and 12) has a thin edge 44d and a thick edge 46d. An outer side surface 50d extends between opposite ends 52d and 54d (FIG. 12) of the thin edge 44d. The outer side surface 50d has a configuration which corresponds to the configuration of an outer side surface 94d of a bone 22d (FIG. 11). The wedge member 36d has flat upper and lower major side surfaces 68d and 70d which are skewed at an acute angle relative to each other and extend between the thin edge 44d and the thick edge 46d of the wedge member 36d.

The wedge member 36d has the same overall configuration as the wedge member 36 of the embodiment of the invention illustrated in FIGS. 2-6. Thus, the side surface 50 (FIG. 12) has the same configuration as the side surface 50 of FIGS. 3 and 4. The upper and lower major side surfaces 68d and 70d (FIGS. 11 and 12) have outer edge portions with the same configuration as the outer edge portion of the major side surfaces 68 and 70 of FIGS. 3 and 4.

When the wedge member 36d has been inserted into a slot formed in a bone in the manner previously explained in

conjunction with the embodiment of the invention illustrated in FIGS. 2-6, mounting strips 60d, 62d, and 64d on the wedge member 36d move into abutting engagement with the outer side surface 94d of the bone 22d (FIG. 12). The mounting strips 60d, 62d, and 64d are fixedly connected with the upper end portion 30d and lower portion 32d of the bone 22d by suitable fasteners 58d. The fasteners 58d retain the wedge member 36d against movement from a position in which the side surface 50d is aligned with the outer side surface 94d of the bone 22d.

As the wedge member 36d is inserted into the slot in the bone 22d, an upper portion 30d (FIG. 11) of the bone 22d is pivoted relative to a lower portion 32d to change the spatial relationship between the upper portion 30d and lower portion 32d of the bone 22d. The upper portion 30d of the bone 22d pivots about an axis which extends parallel to the thin edge 44d of the wedge member 36d. The axis about which the upper portion 30d of the bone pivots extends through the hinge or connector portion 40d of the bone 22d and is parallel to the bottom of the slot formed in the bone 22d to receive the wedge member 36d.

In accordance with a feature of the present invention, the wedge member 36d has a large central opening 134 through which bone may grow. The opening 134 extends between upper and lower major side surfaces 68d and 70d of the wedge member 36d. The opening 134 is configured in such a manner that the upper and lower major side surfaces 68d and 70d of the wedge member 36d engage an outer layer 80d of hard cortical bone throughout movement of the wedge member 36d into the slot formed in the bone 22d.

When the wedge member 36d has moved into the bone 22d, to the position shown in FIGS. 11 and 12, the large opening 134 enables the core 90d of soft cancellous bone to easily grow through the wedge member 36d. If desired, material 130d (FIG. 11) for promoting a growth of bone could be positioned in the opening 134. At this time, the outer layer 80d of hard cortical bone is disposed in abutting engagement with opposite major side surfaces 68d and 70d on the wedge member 36d throughout the extent of the opening to the slot into which the wedge member is inserted. Relatively small openings 74d are provided in the wedge member 36d to enable hard cortical bone to grow through the wedge member.

The opening 134 has a configuration which is similar to but smaller than the overall configuration of the wedge member 36d. Thus, the opening 134 has a flat, rectangular side surface 136 which extends parallel to the thin edge 44d of the wedge member 36d. The opening 134 has an arcuate side surface 138 which is spaced substantially the same distance from the outer side surface 50d throughout the extent of the side surface 138 of the opening 134 and the side surface 50d of the wedge member 36d.

The side surface 138 of the opening 134 is spaced from the outer side surface 50d by a distance which is greater than the thickness of the outer layer 80d of hard cortical bone. Therefore, as the wedge member 36d is inserted into the slot formed in the bone 22d, the outer layer 80d of hard cortical bone engages the upper and lower major side surfaces 68d and 70d of the wedge member 36d. The outer layer 80d of hard cortical bone is in engagement with the upper and lower major side surfaces 68d and 70d of the wedge member 36d when the outer side surface 50d of the wedge member is aligned with the outer side surface 94d of the bone 22d. The outer layer 80d of hard cortical bone is disposed in engagement with the wedge member 36d throughout the extent of the opening to the slot into which the wedge member 36d is inserted.

When the wedge member 36d has been moved into the slot formed in the bone 20d, the mounting strips 60d, 62d and 64d move into abutting engagement with the outer side surface 94d of the bone. Suitable fasteners 58d can then be utilized to connect the wedge member 36d with the upper end portion 30d and the lower portion 32d of the bone 22d. The fasteners 58d maintain the outer side surface 50d on the wedge member 36d in alignment with the outer side surface 94d of the bone 22d.

The wedge member 36d can, upon being positioned relative to the bone and an incision which was made to expose the bone closed, be load bearing. This is because the outer layer 80d of hard cortical bone extends through the hinge portion 40d and can support a load in the usual manner. The outer layer 80d of hard cortical bone is disposed in engagement with the upper and lower major side surfaces 68d and 70d of the rigid wedge member 36d at a location offset to the left (as viewed in FIG. 12) from the hinge or connector portion 40d. Therefore, force can be transmitted between the upper end portion 30d and lower portion 32d (FIG. 11) through the wedge member 36d as soon as the wedge member has been properly installed in the bone 22d.

With the passage of time, the soft cancellous bone 90d grows through and completely fills the opening 134 in the wedge member 36d. Although one specific opening configuration has been illustrated in FIG. 12, it is contemplated that the opening 134 could have any desired configuration. In addition to the bone growth promoting material 130d, the wedge member 36d could be coated with bone growth promoting material. If desired, the small openings 74d could be omitted.

Wedge Member—Fifth Embodiment

In the embodiment of the invention illustrated in FIGS. 1-6, the wedge member has flat major side surfaces. In the embodiment of the invention illustrated in FIGS. 13 and 14, the wedge member has major side surfaces with a stepped configuration. Since the embodiment of the invention illustrated in FIGS. 13 and 14 is generally similar to the embodiment of the invention illustrated in FIGS. 2-6, similar numerals will be utilized to identify similar components, the suffix letter "e" being associated with the numerals of FIGS. 13 and 14 to avoid confusion.

A wedge member 36e is used to change a spatial relationship between an upper end portion 30e and a lower portion 32e of a bone 22e (FIG. 13). The wedge member 36e includes a thin edge 44e and a thick edge 46e. The wedge member 36e has an outer side surface 50e which extends between opposite ends 52e and 54e (FIG. 14) of the thin edge 44e. The wedge member 36e has an upper major side 68e (FIG. 13) and a lower major side 70e.

A plurality of mounting strips 60e, 62e and 64e move into abutting engagement with an outer side surface 94e of the bone 22e when the wedge member 36e is inserted into a slot formed in the bone in the manner previously explained. As the wedge member 36e is inserted into the slot in the bone, the upper end portion 30e of the bone 22e pivots about an axis which extends through a connector or hinge portion 40e of the bone. The axis about which the upper portion 30e of the bone pivots extends parallel to the thin edge 44e of the wedge member 36e.

When the mounting strips 60e, 62e and 64e have moved into abutting engagement with the outer side surface 94e of the bone 22e, the outer side surface 50e is in alignment with the outer side surface 94e of the bone 22e. Suitable fasteners 58e are utilized to connect the wedge member 46e with the upper end portion 30e and lower portion 32e of the bone 22e in the manner previously explained.

In accordance with a feature of this embodiment of the invention, the upper major side 68e of the wedge member 36e has a stepped configuration. Thus, the upper major side 68e of the wedge member 36e includes a flat surface area 150 (FIGS. 13 and 14) which extends at a first, relatively small acute angle relative to the lower major side surface 70e of the wedge member 36e. A second surface area 152 extends from the surface area 150 toward the outer side surface 50e of the wedge member 36e at a second acute angle relative to the lower side surface 70e. The second acute angle, at which the side surface 152 extends relative to the lower side surface 70e (FIG. 13), is greater than the first angle at which the side surface area 150 extends relative to the lower side surface 70e.

Finally, the wedge member 36e includes a surface area 154 which extends outward from the surface area 152 to the outer side surface 50e of the wedge member 36e. The surface 154 slopes at an acute angle relative to the lower side surface 70e of the wedge member 36e. The angle which the surface 154 makes with the lower side surface 70e is greater than the angle which the surface area 150 makes with the lower side surface 70e. The angle which the surface area 150 makes with the lower side surface 70e of the wedge member 36e is less than the angle which the surface area 152 makes with the lower side surface 70e (FIG. 13).

The surface area 154 extends a substantially constant distance from the outer side surface 50e of the wedge member 36e throughout the extent of the surface area 154 (FIG. 14). Since the surface area 152 extends between the surface area 150 and the surface area 154 (FIG. 14), the extent of the surface area 152 varies as a function of the distance of the surface area from a perpendicular to the thin edge 44e and through the center of wedge member 36e. The resulting stepped configuration of the wedge member 36e facilitates initial movement of the wedge member into the slot formed in the bone 22e.

A plurality of openings 74e extend through the wedge member 36e. The openings 74e enable bone to grow through the wedge member 36e. The openings 74e may have a straight cylindrical configuration or may have an open-celled structure. The wedge member 36e may be coated with bone growth promoting material and/or the openings 74e may be at least partially filled with bone growth promoting material.

An outer layer 80e of hard cortical bone is disposed in engagement with the surface area 154 adjacent to the outer side surface 50e of the wedge member 36e. The portion of the outer layer 80e of hard cortical bone exposed by formation of the slot in the bone also engages the lower major side surface 70e of the wedge member 36e. The wedge member 36e is formed of a rigid material which is capable of transmitting force between the upper end portion 30e and the lower portion 32e of the bone 22e. Therefore, the bone is immediately weight supporting when the wedge member 36e is positioned in the bone in the manner illustrated in FIGS. 13 and 14.

Conclusion

In view of the foregoing description, it is apparent that the present invention provides a new and improved method and apparatus for use in changing a spatial relationship between portions of a bone 22 in a patient's body. When this is to be done, an opening is formed in a portion of the patient's body tissue to at least partially expose the bone 22. Force is applied to the bone 22 with a wedge member 36 to move one portion 30 of the bone relative to another portion 32 of the bone. The wedge member 36 may be fixedly connected with either or both portions of the bone. The opening in the

patient's body is then closed with the wedge member 36 disposed in engagement with the bone 22. Force can be transmitted between portions 30 and 32 of the bone 22 through the wedge member 36.

The wedge member 36 may taper from a thick edge 46 to a thin edge 44 and have a side surface 50 which extends from one end 52 of the thin edge, along the thick edge, to the opposite end 54 of the thin edge. The side surface 50 of the wedge member 36 has a cross sectional configuration corresponding to the configuration of a portion of an outer side surface 94 of the bone 22. This enables the wedge member 36 to be aligned with the outer side surface 94 of the bone 22.

The wedge member 36 may be positioned relative to the bone 22 at a location where a layer 80 of hard cortical bone encloses soft cancellous bone 90. Opposite ends 52 and 54 of the thin edge 44 of the wedge member 36 may be positioned in engagement with the hard cortical bone 80 while a central portion of the thin edge 44 of the wedge member 36 engages the soft cancellous bone. In addition, the layer 80 of hard cortical bone may engage the wedge member 36 adjacent to the side surface 50 of the wedge member.

It is contemplated that the wedge member 36 may have many different constructions. It is believed that it will be advantageous to form the wedge member 36 with one or more openings 74 through which bone can grow. The wedge member 36 may be hollow and contain material 130 which promotes the growth of bone through the wedge member.

A screw member 100 may extend ahead of the thin leading edge 44 of the wedge member 36 and engage hard cortical bone. Force may be transmitted from the screw member 100 to the wedge member 36 to move the wedge member relative to the bone. Alternatively, the wedge member 36 may have a circular cross sectional configuration with an external thread convolution 116 to enable the wedge member to be moved into an opening in a bone by rotating the wedge member.

Having described the invention, the following is claimed:

1. A method of changing a spatial relationship between first and second portions of a bone in a patient's body, said method comprising the steps of moving a central portion of a thin leading edge of a wedge member through a layer of hard cortical bone into engagement with soft cancellous bone with portions of the thin leading edge of the wedge member on opposite sides of the central portion in engagement with the layer of hard cortical bone, continuing movement of the wedge member relative to the bone, interrupting movement of the wedge member relative to the bone with the central portion of the thin leading edge of the wedge member in engagement with soft cancellous bone and with opposite end portions of the thin leading edge of the wedge member in engagement with the layer of hard cortical bone, and, thereafter, transmitting force between the layer of hard cortical bone and the thin leading edge of the wedge member.

2. A method as set forth in claim 1 wherein said step of continuing movement of the wedge member relative to the bone includes moving at least one of the end portions of the leading edge of the wedge member out of engagement with the layer of hard cortical bone and back into engagement with the layer of hard cortical bone.

3. A method as set forth in claim 1 wherein said step of continuing movement of the wedge member relative to the bone includes sliding opposite major side surfaces of the wedge member on the soft cancellous bone and on the outer layer of hard cortical bone with areas on the major side

surfaces of the wedge member which engage the soft cancellous bone being disposed between areas on the major side surfaces of the wedge member which engage the hard cortical bone.

4. A method as set forth in claim 1 wherein said step of continuing movement of the wedge member relative to the bone includes effecting relative movement between the first and second portions of the bone under the influence of force transmitted from the wedge member to the layer of hard cortical bone.

5. A method as set forth in claim 1 further including the step of growing bone through openings in the wedge member while the central portion of the thin leading edge of the wedge member is in engagement with soft cancellous bone and the opposite end portions of the thin leading edge of the wedge member are in engagement with the layer of hard cortical bone.

6. A method as set forth in claim 1 wherein said step of transmitting force between the layer of hard cortical bone and the thin leading edge of the wedge member is performed while the spatial relationship between the first and second portions of the bone remains constant.

7. A method as set forth in claim 1 wherein said steps of moving a central portion of the thin leading edge of the wedge member through a layer of hard cortical bone and continuing movement of the wedge member relative to the bone includes moving an opening which extends through the wedge member from a location offset to one side of the soft cancellous bone to a location in which the opening through the wedge member is aligned with the soft cancellous bone to enable soft cancellous bone to grow through the opening in the wedge member.

8. A method as set forth in claim 1 wherein the wedge member includes a pair of opposite major side surfaces which extend between the thin leading edge of the wedge member and a thick trailing edge of the wedge member, said step of interrupting movement of the wedge member relative to the bone being performed with the layer of hard cortical bone being disposed in engagement with the opposite major side surfaces of the wedge member along continuous surface areas which extend between the thin leading edge of the wedge member and the thick trailing edge of the wedge member.

9. A method as set forth in claim 1 wherein said step of continuing movement of the wedge member relative to the bone includes engaging the layer of hard cortical bone at a location ahead of the thin leading edge of the wedge member with a screw and transmitting force through the screw to the wedge member.

10. A method as set forth in claim 1 further including the step of fixedly connecting the wedge member with the layer of hard cortical bone to hold the wedge member against movement relative to the bone.

11. A method of changing a spatial relationship between first and second portions of a bone in a patient's body, said method comprising the steps of forming a slot in the bone to at least partially separate the first portion of the bone from the second portion of the bone, forcing a wedge member into the slot in the bone with a thin edge of the wedge member leading and a thick edge of the wedge member trailing to move the first portion of the bone from a first orientation relative to the second portion of the bone to a second orientation relative to the second portion of the bone, fixedly connecting the wedge member with the bone, and transmitting force between the first and second portions of the bone through the wedge member while the first portion of the bone is in the second orientation and while the wedge member is held against movement relative to the bone.

12. A method as set forth in claim 11 wherein said step of fixedly connecting the wedge member with the bone includes fixedly connecting the wedge member with the first portion of the bone with a first connector and fixedly connecting the wedge member with the second portion of the bone with a second connector after performing said step of forcing the wedge member into the slot in the bone.

13. A method as set forth in claim 11 wherein the wedge member tapers from a thick edge portion to a thin edge portion and has a side edge portion which extends between the thick edge portion and thin edge portion of said wedge member, said step of forcing the wedge member into the slot in the bone includes moving the side edge portion of the wedge member into alignment with the bone.

14. A method as set forth in claim 11 wherein said step of forming a slot includes forming a slot having an opening which is formed in a major portion of the periphery of the bone, said step of transmitting force between the first and second portions of the bone through the wedge member includes transmitting force between peripheral portions of the bone and opposite sides of the wedge member at areas which are coextensive with the opening to the slot.

15. A method as set forth in claim 11 wherein the step of forming a slot includes forming a slot having an opening which extends inward from an outer side surface of the bone, said step of forcing a wedge member into the slot includes moving an outer side surface on the wedge member into alignment with the outer side surface of the bone, said step of fixedly connecting the wedge member with the bone being performed with the outer side surface on the wedge member aligned with the outer side surface of the bone.

16. A method of changing a spatial relationship between first and second portions of a bone in a patient's body, said method comprising the steps of providing a wedge member which tapers from a thick edge to a thin edge and has a side surface which extends from one end of the thin edge, along the thick edge, to an end of the thin edge opposite from the one end, said side surface of said wedge member has a configuration corresponding to the configuration of a portion of an outer side surface of the bone, and moving the first portion of the bone relative to the second portion of the bone by moving the wedge member into the bone to a position in which the side surface of the wedge member is aligned with the outer side surface of the bone.

17. A method as set forth in claim 16 wherein said step of moving a first portion of the bone relative to a second portion of the bone includes applying force to the bone with the wedge member and pivoting the first portion of the bone relative to the second portion of the bone about an axis extending through a portion of the bone interconnecting the first and second portions of the bone.

18. A method as set forth in claim 16 further including the steps of fixedly connecting the wedge member with the first portion of the bone and fixedly connecting the wedge member with the second portion of the bone.

19. A method as set forth in claim 16 wherein the wedge member includes a pair of major surfaces which extend between the thick and thin edges of said wedge member, said side surface of said wedge member extends between said major surfaces of said wedge member, said step of moving the first portion of the bone relative to the second portion of the bone by moving the wedge member into the bone includes applying force against the first and second portions of the bone with the major surfaces of the wedge member.

20. A method as set forth in claim 16 wherein said step of moving the first portion of the bone relative to the second portion of the bone by moving the wedge member into the

bone includes engaging the bone with a screw and transmitting force from the screw to the wedge member.

21. A method of changing the relationship between first and second portions of a bone in a patient's body, said method comprising the steps of forming an opening in the bone at a location between the first and second portions of the bone, moving a wedge member into the opening, said step of moving the wedge member into the opening includes rotating the wedge member about an axis which extends through thick and thin end portions of the wedge member, and pivoting the first portion of the bone relative to the second portion of the bone about an axis extending through bone interconnecting the first and second portions of the bone under the influence of force transmitted from the wedge member to the first portion of the bone as the wedge member is rotated.

22. A method as set forth in claim 21 further including the step of fixedly connecting the thick end portion of the wedge member to the first and second portions of the bone after having performed said step of rotating the wedge member.

23. A method of changing the spatial relationship between first and second portions of a bone in a patient's body, said method comprising the steps of forming an opening in the bone at a location between the first and second portions of the bone, moving a wedge member which tapers from a thick end portion to a thin end portion into the opening with the thin end portion of the wedge member leading, engaging bone interconnecting the first and second portions of the bone with a screw member, and rotating the screw member relative to the wedge member, said step of moving the wedge member into the opening includes transmitting force from the screw member to the wedge member while rotating the screw member.

24. A method as set forth in claim 23 further including the step of pivoting the first portion of the bone relative to the second portion of the bone about an axis which extends through the portion of the bone interconnecting the first and second portions of the bone under the influence of force transmitted from the wedge member to the first portion of the bone while moving the wedge member into the opening and rotating the screw member.

25. A method of changing a spatial relationship between first and second portions of a bone in a patient's body, said method comprising the steps of applying force against the first and second portions of the bone with a wedge member, moving the first portion of the bone relative to the second portion of the bone under the influence of force applied against the first portion of the bone by the wedge member, and growing bone between the first and second portions of the bone through the wedge member.

26. A method as set forth in claim 25 further including the step of maintaining the wedge member stationary relative to the first and second portions of the bone while growing bone through the wedge member.

27. A method as set forth in claim 25 wherein the wedge member has major side surfaces which engage the first and second portions of the bone and a minor side surface which extends between said major side surfaces, said method further including the step of moving the wedge member to a position in which the minor side surface of the wedge member is aligned with an outer side surface of the bone during performance of said step of moving the first portion of the bone relative to the second portion of the bone.

28. A method as set forth in claim 25 wherein said wedge member tapers from a thick end portion to a thin end portion, said wedge member being disposed in engagement with hard cortical bone along surface areas which extend between the

thin end portion and the thick end portion of the wedge member upon completion of said step of moving the first portion of the bone relative to the second portion of the bone, said step of growing bone between the first and second portions of the bone through the wedge member includes growing hard cortical bone through the surface areas which extend between the thin end portion and the thick end portion of the wedge member.

29. A method as set forth in claim 25 wherein said step of applying force against first and second portions of the bone with a wedge member includes pulling the wedge member into an opening between the first and second portions of the bone.

30. A method as set forth in claim 25 wherein said step of applying force against the first and second portions of the bone with a wedge member includes rotating the wedge member relative to the first and second portions of the bone about an axis which extends through the wedge member.

31. A method as set forth in claim 25 wherein the wedge member tapers from a wide end portion to a thin end portion, said step of growing bone between the first and second portions of the bone through the wedge member includes growing bone through a portion of the wedge member disposed between the wide end portion and the thin end portion of the wedge member.

32. A method as set forth in claim 25 wherein the wedge member tapers from a thick end portion to a thin end portion, said step of applying force against the first and second portions of the bone includes pivoting the first portion of the bone relative to the second portion of the bone about an axis extending through bone interconnecting the first and second portions of the bone with the thin end portion of the wedge member extending parallel to the axis.

33. A method of changing a spatial relationship between first and second portions of a bone in a patient's body, said method comprising the steps of forming an opening in a portion of the patient's body tissue to at least partially expose the bone, moving the second portion of the bone relative to the first portion of the bone, said step of moving the second portion of the bone relative to the first portion of the bone includes applying force to hard cortical bone with a wedge member, said step of applying force to hard cortical bone with a wedge member includes applying force to hard cortical bone with a wedge member having a plurality of openings through which bone can grow, closing the opening in the patient's body tissue with the wedge member disposed in engagement with the hard cortical bone, and, thereafter, transmitting force between the first and second portions of the bone through the wedge member.

34. A method as set forth in claim 33 wherein said wedge member tapers from a thick end portion to a thin end portion, said wedge member being disposed in engagement with the hard cortical bone along a surface area which extends between the thin end portion of said wedge member and the thick end portion of said wedge member upon completion of said step of moving the second portion of the bone relative to the first portion of the bone and during performance of said step of transmitting force between the first and second portions of the bone through the wedge member.

35. A method as set forth in claim 33 wherein said step of moving the first portion of the bone relative to the second portion of the bone includes pivoting the first portion of the bone relative to the second portion of the bone about an axis extending through bone interconnecting the first and second portions of the bone.

36. A method as set forth in claim 33 wherein the wedge member is formed of a porous material, said method further

includes growing bone through openings defined by the porous material of the wedge member.

37. A method as set forth in claim 33 wherein the wedge member is formed of bone, said method further includes growing bone through openings defined by the bone forming the wedge member.

38. A method as set forth in claim 33 further including the step of providing bone growth promoting material in said wedge member to promote growth of bone through the openings in the wedge member.

39. A method as set forth in claim 33 further including the step of positioning bone growth promoting material in a compartment in said wedge member to promote growth of bone.

40. A method of changing a spatial relationship between first and second portions of a bone in a patient's body, said method comprising the steps of providing a wedge member which tapers from a thick edge to a thin edge and has a side surface which extends from one end of the thin edge, along

20 the thick edge, to an end of the thin edge opposite from the one end, said side surface of said wedge member has a configuration corresponding to the configuration of a portion of an outer side surface of the bone, and moving the first portion of the bone relative to the second portion of the bone by moving the wedge member into the bone to a position in which the side surface of the wedge member is aligned with the outer side surface of the bone, the wedge member has a plurality of openings to enable bone to grow through said wedge member while the side surface of the wedge member is aligned with the outer side surface of the bone.

41. A method as set forth in claim 40 wherein the wedge member is formed of a porous material, said method further includes growing bone through openings defined by the porous material of the wedge member.

42. A method as set forth in claim 40 wherein the wedge member is formed of bone, said method further includes growing bone through openings defined by the bone forming the wedge member.

43. A method as set forth in claim 40 further including the step of providing bone growth promoting material in said wedge member to promote growth of bone through the openings in the wedge member.

44. A method as set forth in claim 40 further including the step of positioning bone growth promoting material in a compartment in said wedge member to promote growth of bone.

45. A method of changing a spatial relationship between first and second portions of a bone in a patient's body, said method comprising the steps of applying force against the first and second portions of the bone with a wedge member, said step of applying force against first and second portions of the bone with the wedge member includes applying force against hard cortical bone with opposite sides of the wedge member, moving the first portion of the bone relative to the second portion of the bone under the influence of force applied against the first portion of the bone by the wedge member, and growing bone between the first and second portions of the bone through the wedge member, said step of growing bone between the first and second portions of the bone includes growing soft cancellous bone through openings in the opposite sides of the wedge member.

46. A method as set forth in claim 45 wherein the wedge cancellous bone through openings in opposite sides of the wedge member includes growing bone through openings defined by the porous material of the wedge member.

47. A method as set forth in claim 45 wherein the wedge member is formed of bone, said step of growing soft

cancellous bone through openings in opposite sides of the wedge member includes growing bone through openings defined by the bone forming the wedge member.

48. A method as set forth in claim 45 further including the step of providing bone growth promoting material in said wedge member to promote growth of bone through the openings in the wedge member.

49. A method as set forth in claim 45 further including the step of positioning bone growth promoting material in a compartment in said wedge member to promote growth of bone.

50. A method as set forth in claim 45 wherein said wedge member tapers from a thick end portion to a thin end portion, said wedge member being disposed in engagement with the hard cortical bone along a surface area which extends between the thin end portion of said wedge member and the thick end portion of said wedge member upon completion of said step of moving the first portion of the bone relative to the second portion of the bone and during performance of said step of growing soft cancellous bone through openings in opposite sides of said wedge member.

51. A method set forth in claim 45 wherein said step of applying force against the first and second portions of the bone with a wedge member includes pulling the wedge member into an opening between the first and second portions of the bone.

52. A method as set forth in claim 45 wherein the hard cortical bone has a first portion which is disposed along one side of the bone and second and third portions which are disposed along opposite sides of the bone which extend transverse to the one side of the bone, said step of applying force against hard cortical bone with opposite sides of the wedge member includes engaging the first, second and third portions of the hard cortical bone with the wedge member.

53. A method as set forth in claim 45 wherein said step of applying force against hard cortical bone with opposite sides of a wedge member includes rotating the wedge member relative to the hard cortical bone about an axis which extends through the wedge member.

54. A method as set forth in claim 45 wherein the wedge member tapers from a thick end portion to a thin end portion, said step of applying force against hard cortical bone with opposite sides of a wedge member includes moving the wedge member toward an axis extending through cortical bone interconnecting the first and second portions of the bone with the thin end portion of the wedge member extending parallel to the axis extending through cortical bone.

55. A method as set forth in claim 45 wherein said step of moving the first portion of the bone relative to the second portion of the bone includes pivoting the first portion of the bone relative to the second portion of the bone about an axis extending through bone interconnecting the first and second portions of the bone.

56. A method as set forth in claim 45 further including the steps of forming an opening in a portion of the patient's body tissue to at least partially expose the first and second portions of the bone, closing the opening in the patient's body tissue with the wedge member disposed in engagement with the first and second portions of the bone, and, thereafter, transmitting force between the first and second portions of the bone through the wedge member.

57. A method of changing a spatial relationship between first and second portions of a bone in a patient's body, said method comprising the steps of applying force against the first and second portions of the bone with a wedge member, moving the first portion of the bone relative to the second

portion of the bone under the influence of force applied against the first portion of the bone by the wedge member, promoting growth of bone through said wedge member by providing bone growth promoting material in the wedge member, and growing bone between the first and second portions of the bone through the wedge member.

58. A method as set forth in claim 57 further including the step of maintaining the wedge member stationary relative to the first and second portions of the bone while growing bone through the wedge member.

59. A method as set forth in claim 57 wherein said step of applying force against first and second portions of the bone with the wedge member includes applying force against hard cortical bone with opposite sides of the wedge member, said step of growing bone between the first and second portions of the bone includes growing soft cancellous bone through openings in the opposite sides of the wedge member.

60. A method as set forth in claim 57 wherein the wedge member has major side surfaces which engage the first and second portions of the bone and a minor side surface which extends between said major side surfaces, said method further including the step of moving the wedge member to a position in which the minor side surface of the wedge member is aligned with an outer side surface of the bone during performance of said step of moving the first portion of the bone relative to the second portion of the bone.

61. A method as set forth in claim 57 wherein said wedge member tapers from a thick end portion to a thin end portion, said wedge member being disposed in engagement with hard cortical bone along surface areas which extend between the thin end portion and the thick end portion of the wedge member upon completion of said step of moving the first portion of the bone relative to the second portion of the bone, said step of growing bone between the first and second portions of the bone through the wedge member includes growing hard cortical bone through the surface areas which extend between the thin end portion and the thick end portion of the wedge member.

62. A method as set forth in claim 57 wherein said step of applying force against first and second portions of the bone with a wedge member includes pulling the wedge member into an opening between the first and second portions of the bone.

63. A method as set forth in claim 57 wherein said step of applying force against the first and second portions of the bone with a wedge member includes rotating the wedge member relative to the first and second portions of the bone about an axis which extends through the wedge member.

64. A method as set forth in claim 57 wherein the wedge member tapers from a wide end portion to a thin end portion, said step of growing bone between the first and second portions of the bone through the wedge member includes growing bone through a portion of the wedge member disposed between the wide end portion and the thin end portion of the wedge member.

65. A method as set forth in claim 57 wherein the wedge member tapers from a thick end portion to a thin end portion, said step of applying force against the first and second portions of the bone includes pivoting the first portion of the bone relative to the second portion of the bone about an axis extending through bone interconnecting the first and second portions of the bone with the thin end portion of the wedge member extending parallel to the axis.

66. A method as set forth in claim 57 further including the steps of forming an opening in a portion of the patient's body tissue to at least partially expose the first and second portions of the bone, closing the opening in the patient's

body tissue with the wedge member disposed in engagement with the first and second portions of the bone, and, thereafter, transmitting force between the first and second portions of the bone through the wedge member.

67. A method as set forth in claim 57 wherein the wedge member is formed of a porous material, said step of growing bone between the first and second portions of the bone through the wedge member includes growing bone through openings defined by the porous material of the wedge member.

68. A method as set forth in claim 57 wherein the wedge member is formed of bone, said step of growing bone between the first and second portions of the bone through the wedge member includes growing bone through openings defined by the bone forming the wedge member.

69. A method as set forth in claim 57 wherein said step of providing bone growth promoting material in the wedge member includes the step of positioning bone growth promoting material in said wedge member to promote growth of bone through openings in the wedge member.

70. A method as set forth in claim 57 wherein said step of providing bone growth promoting material in the wedge member includes the step of positioning bone growth promoting material in a compartment in said wedge member to promote growth of bone.

71. A method as set forth in claim 57 wherein said step of providing bone growth promoting material in the wedge member includes the step of positioning bone growth promoting material in an opening which extends between opposite major sides of the wedge member.

72. A method as set forth in claim 57 wherein said wedge member tapers from a thick end portion to a thin end portion, said wedge member being disposed in engagement with the hard cortical bone along a surface area which extends between the thin end portion of said wedge member and the thick end portion of said wedge member upon completion of said step of moving the first portion of the bone relative to the second portion of the bone and during performance of said step of growing bone between the first and second portions of the bone through the wedge member.

73. A method as set forth in claim 57 wherein said step of applying force against the first and second portions of the bone with a wedge member includes applying force to hard cortical bone with a wedge member having a plurality of openings through which bone can grow.

74. A method as set forth in claim 57 wherein said step of applying force against the first and second portions of the bone with a wedge member includes pulling the wedge member into an opening between the first and second portions of the bone.

75. A method as set forth in claim 57 wherein said step of applying force against the first and second portions of the bone with a wedge member includes rotating the wedge member relative to the bone about an axis which extends through the wedge member.

76. A method as set forth in claim 57 wherein the wedge member tapers from a thick end portion to a thin end portion, said step of applying force against the first and second portions of the bone with a wedge member includes moving the wedge member toward an axis extending through cortical bone interconnecting the first and second portions of the bone with the thin end portion of the wedge member extending parallel to the axis extending through cortical bone.

77. A method of changing a spatial relationship between first and second portions of a bone in a patient's body, said method comprising the steps of forming an opening in a

portion of the patient's body tissue to provide access to the bone, moving the second portion of the bone relative to the first portion of the bone, said step of moving the second portion of the bone relative to the first portion of the bone includes applying force to hard cortical bone with a wedge member, closing the opening in the patient's body tissue with the wedge member disposed in engagement with the hard cortical bone, and, thereafter, transmitting force between the first and second portions of the bone through the wedge member.

78. A method as set forth in claim 77 wherein said wedge member tapers from a thick end portion to a thin end portion, said wedge member being disposed in engagement with the hard cortical bone along a surface area which extends between the thin end portion of said wedge member and the thick end portion of said wedge member upon completion of said step of moving the second portion of the bone relative to the first portion of the bone and during performance of said step of transmitting force between the first and second portions of the bone through the wedge member.

79. A method as set forth in claim 77 wherein said step of applying force to hard cortical bone with a wedge member includes pulling the wedge member into an opening between the first and second portions of the bone.

80. A method as set forth in claim 77 wherein the hard cortical bone has a first portion which is disposed along one side of the bone and second and third portions which are disposed along opposite sides of the bone which extend transverse to the one side of the bone, said step of applying force to hard cortical bone with the wedge member includes engaging the first, second and third portions of the hard cortical bone with the wedge member.

81. A method as set forth in claim 77 wherein said step of applying force to hard cortical bone with a wedge member includes rotating the wedge member relative to the hard cortical bone about an axis which extends through the wedge member.

82. A method as set forth in claim 77 wherein the wedge member tapers from a thick end portion to a thin end portion, said step of applying force to hard cortical bone with a wedge member includes moving the wedge member toward the axis extending through cortical bone interconnecting the first and second portions of the bone with the thin end portion of the wedge member extending parallel to the axis extending through cortical bone.

83. A method as set forth in claim 77 wherein said step of moving the first portion of the bone relative to the second portion of the bone includes pivoting the first portion of the bone relative to the second portion of the bone about an axis extending through the bone interconnecting the first and second portions of the bone.

84. A method of changing a spatial relationship between first and second portions of a bone in a patient's body, said method comprising the steps of providing a wedge member formed of bone, forming an opening in a portion of the patient's body tissue to obtain access to the first and second portions of the bone in the patient's body, moving the second portion of the bone relative to the first portion of the bone, said step of moving the second portion of the bone relative to the first portion of the bone includes applying force to the first and second portions of the bone in the patient's body with the wedge member formed of bone, closing the opening in the patient's body tissue with the wedge member formed of bone disposed in engagement with the first and second portions of the bone in the patient's body, and, thereafter,

transmitting force between the first and second portions of the bone in the patient's body through the wedge member formed of bone.

85. A method as set forth in claim 84 wherein said wedge member formed of bone tapers from a thick end portion to a thin end portion, said wedge member formed of bone being disposed in engagement with the hard cortical bone which forms part of the first and second portions of the bone in the patient's body along a surface area which extends between the thin end portion of said wedge member formed of bone and the thick end portion of said wedge member formed of bone upon completion of said step of moving the second portion of the bone in the patient's body relative to the first portion of the bone in the patient's body and during performance of said step of transmitting force between the first and second portions of the bone in the patient's body through the wedge member formed of bone.

86. A method as set forth in claim 84 wherein said step of applying force to the first and second portions of the bone in the patient's body with a wedge member formed of bone includes applying force to hard cortical bone with a wedge member formed of bone.

87. An apparatus for use in changing a spatial relationship between first and second portions of a bone in a patient's body, said apparatus comprising a wedge member which is formed of bone and is movable into an opening in the bone in the patient's body to apply force which is transmitted to the first and second portions of the bone in the patient's body and expands the opening, said wedge member formed of bone has first and second major sides which transmit force to the first and second portions of the bone in the patient's body, said first and second major sides of said wedge member formed of bone extend at an acute angle to each other and extend between a thin edge portion and a thick edge portion of said wedge member formed of bone, said wedge member formed of bone having a minor side which extends between said first and second major sides.

88. An apparatus as set forth in claim 87 further including a connector which connects said wedge member formed of bone with at least one of the first and second portions of the bone in the patient's body.

89. An apparatus as set forth in claim 87 further including an opening which extends between said first and second major sides of said wedge member formed of bone, said opening having a first side surface which extends parallel to said thin edge portion of said wedge member formed of bone and a second side surface having a configuration similar to the configuration of said minor side of said wedge member formed of bone, said second side surface being smaller than said minor side of said wedge member formed of bone.

90. An apparatus as set forth in claim 87 wherein said first and second major sides of said wedge member formed of bone define a plurality of openings through which bone can grow.

91. A method of changing a spatial relationship between first and second portions of a bone in a patient's body, said method comprising the steps of applying force against the first and second portions of the bone with a wedge member, moving the first portion of the bone relative to the second portion of the bone under the influence of force applied against the first portion of the bone by the wedge member, and moving the wedge member to a position in which surface areas on the wedge member are aligned with surface areas on opposite sides of the bone.

92. A method as set forth in claim 91 further including the step of maintaining the wedge member stationary relative to the first and second portions of the bone while growing bone through the wedge member.

93. A method as set forth in claim 91 wherein said step of applying force against first and second portions of the bone

with the wedge member includes applying force against hard cortical bone with opposite sides of the wedge member, said method further includes the step of growing bone through openings in opposite sides of the wedge member.

94. A method as set forth in claim 93 further including the step of promoting growth of bone through the openings in the wedge member by providing bone growth promoting material in the wedge member.

95. A method as set forth in claim 91 wherein the wedge member has major side surfaces which engage the first and second portions of the bone and a minor side surface which extends between said major side surfaces, said step of moving the wedge member to a position in which surface areas on the wedge member are aligned with surface areas on opposite sides of the bone includes moving the wedge member to a position in which the minor side surface of the wedge member is aligned with an outer side surface of the bone.

96. A method as set forth in claim 91 wherein said wedge member tapers from a thick end portion to a thin end portion, said wedge member being disposed in engagement with hard cortical bone along surface areas which extend between the thin end portion and the thick end portion of the wedge member upon completion of said step of moving the wedge member to a position in which surface areas on the wedge member are aligned with surface areas on opposite sides of the bone.

97. A method as set forth in claim 91 wherein said step of applying force against first and second portions of the bone with a wedge member includes pulling the wedge member into an opening between the first and second portions of the bone.

98. A method as set forth in claim 91 wherein the wedge member tapers from a wide end portion to a thin end portion, said method further includes growing bone through a portion of the wedge member disposed between the wide end portion and the thin end portion of the wedge member while the surface areas on the wedge member are aligned with the surface areas on opposite sides of the bone.

99. A method as set forth in claim 91 wherein the wedge member tapers from a thick end portion to a thin end portion, said step of applying force against the first and second portions of the bone includes pivoting the first portion of the bone relative to the second portion of the bone about an axis extending through bone interconnecting the first and second portions of the bone with the thin end portion of the wedge member extending parallel to the axis.

100. A method of changing a spatial relationship between first and second portions of a bone in a patient's body, said method comprising the steps of applying force against the first and second portions of the bone with a wedge member, moving the first portion of the bone relative to the second portion of the bone under the influence of force applied against the first portion of the bone by the wedge member, and thereafter, transmitting an external force applied against the patient's body between the first and second portions of the bone through the wedge member.

101. A method as set forth in claim 100 further including the step of maintaining the wedge member stationary relative to the first and second portions of the bone while growing bone through the wedge member.

102. A method as set forth in claim 100 wherein said step of transmitting an external force applied against the patient's body between the first and second portions of the bone through the wedge member includes transmitting force between hard cortical bone and opposite sides of the wedge member.

103. A method as set forth in claim 100 further including the step of promoting growth of bone through the wedge member by providing bone growth promoting material in the wedge member.

104. A method as set forth in claim 100 wherein the wedge member has major side surfaces which engage the first and second portions of the bone and a minor side surface which extends between said major side surfaces, said method further including the step of moving the wedge member to a position in which the minor side surface of the wedge member is aligned with an outer side surface of the bone.

105. A method as set forth in claim 100 wherein said wedge member tapers from a thick end portion to a thin end portion, said wedge member being disposed in engagement with hard cortical bone along surface areas which extend between the thin end portion and the thick end portion of the wedge member upon completion of said step of moving the first portion of the bone relative to the second portion of the bone.

106. A method as set forth in claim 100 wherein said step of applying force against first and second portions of the bone with a wedge member includes pulling the wedge member into an opening between the first and second portions of the bone.

107. A method as set forth in claim 100 wherein said step of applying force against the first and second portions of the bone with a wedge member includes rotating the wedge member relative to the first and second portions of the bone about an axis which extends through the wedge member.

108. A method as set forth in claim 100 wherein the wedge member tapers from a wide end portion to a thin end portion, said method further includes growing bone through a portion of the wedge member disposed between the wide end portion and the thin end portion of the wedge member.

109. A method as set forth in claim 100 wherein the wedge member tapers from a thick end portion to a thin end portion, said step of applying force against the first and second portions of the bone includes pivoting the first portion of the bone relative to the second portion of the bone about an axis extending through bone interconnecting the first and second portions of the bone with the thin end portion of the wedge member extending parallel to the axis.

110. An apparatus for use in changing a spatial relationship between first and second portions of a bone in a patient's body, said apparatus comprising a wedge member which is movable into an opening in the bone to apply force which is transmitted to the first and second portions of the bone and expands the opening, said wedge member having first and second major side surfaces which transmit force to the first and second portions of the bone upon movement of said wedge member into the opening in the bone, and bone growth promoting material disposed on said wedge member to promote growth of bone between said wedge member and said first and second portions of the bone.

111. An apparatus as set forth in claim 110 wherein said wedge member includes compartment means disposed between said first and second major side surfaces for holding bone growth promoting material and a plurality of passages which extend between said compartment means and said first and second major side surfaces.

112. An apparatus as set forth in claim 110 further including a screw member which extends through a portion of said wedge member, said screw member having an end portion which extends past said thin edge portion of said wedge member in a direction away from said thick edge portion of said wedge member, and thread means disposed on said end portion of said screw member for engaging the bone.

113. An apparatus as set forth in claim 110 further including fastener means for fixedly connecting said wedge member with the first and second portions of the bone.

114. An apparatus as set forth in claim 110 wherein said wedge member is formed of a porous material to enable bone to grow into said wedge member.

115. An apparatus as set forth in claim 110 wherein said first and second major side surfaces of said wedge member have peripheral edge portions with a configuration which is the same as a cross sectional configuration of the bone adjacent to the opening in the bone.

116. A method of changing a spatial relationship between first and second portions of a bone in a patient's body, said method comprising the steps of moving a wedge member through a layer of hard cortical bone into engagement with soft cancellous bone with portions of the wedge member in engagement with the layer of hard cortical bone, interrupting movement of the wedge member relative to the bone with the wedge member in engagement with soft cancellous bone and the layer of hard cortical bone, and, thereafter, transmitting force between the layer of hard cortical bone and the wedge member while the wedge member is in engagement with the soft cancellous bone.

117. A method as set forth in claim 116 wherein said step of moving a wedge member through a layer of hard cortical bone into engagement with soft cancellous bone includes moving a portion of the wedge member out of engagement with the layer of hard cortical bone and back into engagement with the layer of hard cortical bone.

118. A method as set forth in claim 116 wherein said step of moving a wedge member through a layer of hard cortical bone into engagement with soft cancellous bone includes sliding opposite major side surfaces of the wedge member on the soft cancellous bone and on the layer of hard cortical bone with areas on the major side surfaces of the wedge member which engage the soft cancellous bone being disposed between areas on the major side surfaces of the wedge member which engage the hard cortical bone.

119. A method as set forth in claim 116 wherein said step of moving a wedge member through a layer of hard cortical bone into engagement with soft cancellous bone includes effecting relative movement between the first and second portions of the bone under the influence of force transmitted from the wedge member to the layer of hard cortical bone.

120. A method as set forth in claim 116 further including the step of growing bone through openings in the wedge member while the wedge member is in engagement with soft cancellous bone and the wedge member is in engagement with the layer of hard cortical bone.

121. A method as set forth in claim 116 wherein said step of transmitting force between the layer of hard cortical bone and the wedge member is performed while the spatial relationship between the first and second portions of the bone remains constant.

122. A method as set forth in claim 116 wherein said steps of moving a wedge member through a layer of hard cortical bone includes moving an opening which extends through the wedge member from a location offset to one side of the soft cancellous bone to a location in which the opening through the wedge member is aligned with the soft cancellous bone to enable soft cancellous bone to grow through the opening in the wedge member.

123. A method as set forth in claim 116 wherein the wedge member includes a pair of opposite major side surfaces, said step of interrupting movement of the wedge member relative to the bone being performed with the layer of hard cortical bone being disposed in engagement with the opposite major

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side surfaces of the wedge member along continuous surface areas which extend between a leading edge of the wedge member and a trailing edge of the wedge member.

124. A method as set forth in claim 116 further including the steps of engaging the layer of hard cortical bone with a screw and transmitting force through the screw to the wedge member.

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125. A method as set forth in claim 116 further including the step of fixedly connecting the wedge member with the layer of hard cortical bone to hold the wedge member against movement relative to the bone.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,086,593

DATED : July 11, 2000

INVENTOR(S) : Peter M. Bonutti

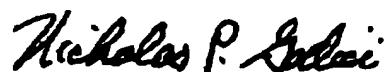
It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 17, line 66, after "the" delete "outer"
Column 20, line 59, change "ember" to "member"
Column 22, Line 31, change "fourth" to "forth"
Column 22, line 62, change "fourth" to "forth"
Column 22, line 63, before "cancellous" insert "member is
formed of a porous material, said step of growing soft"
Column 25, line 5, change "fourth" to "forth"
Column 27, line 49, change "aid" to "said"
Column 29, line 9, change "ember" to "member"

Signed and Sealed this

Twenty-second Day of May, 2001

Attest:



NICHOLAS P. GODICI

Attesting Officer

Acting Director of the United States Patent and Trademark Office